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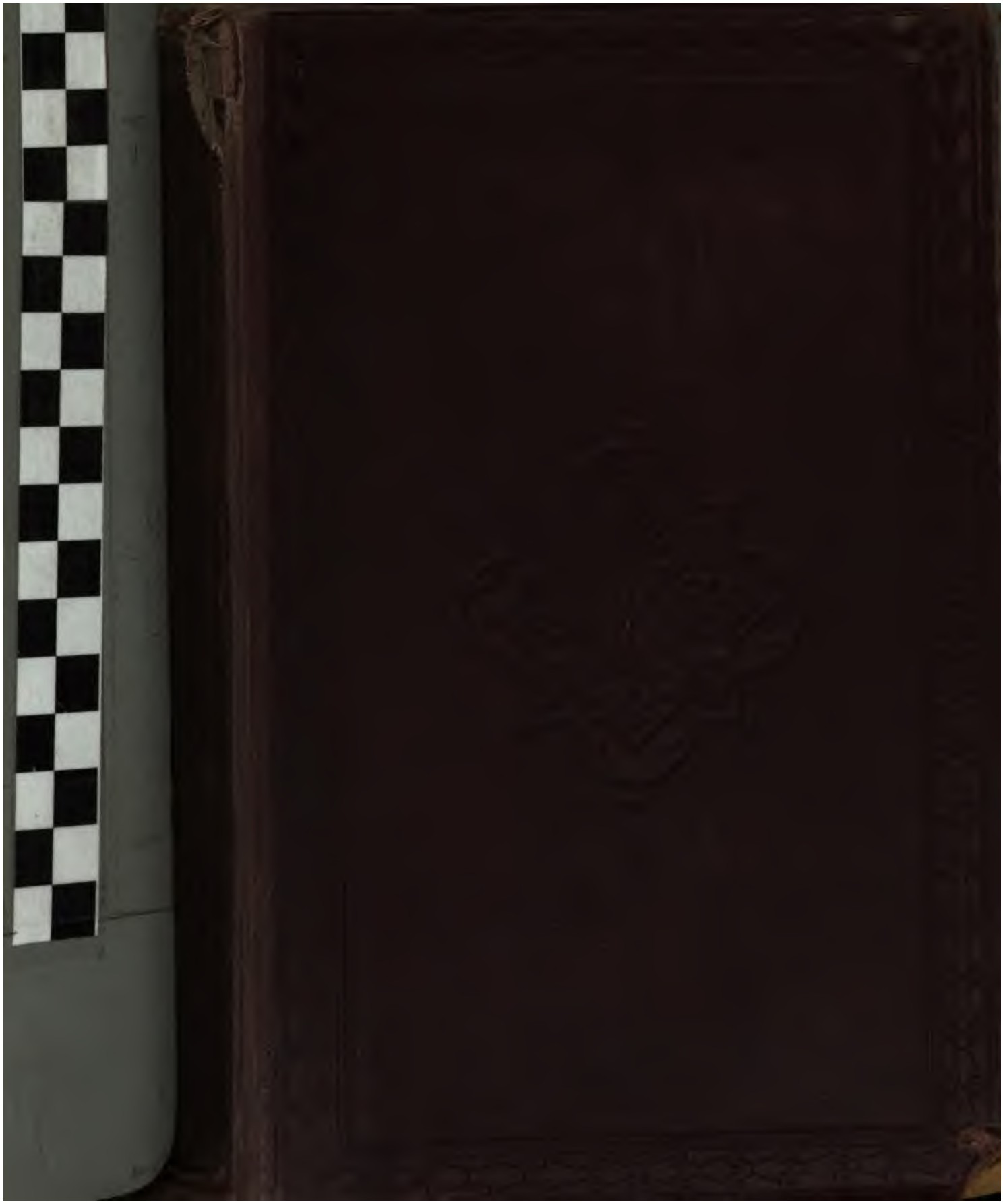

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QUAIN'S ANATOMY.

QUAIN'S

ELEMENTS OF ANATOMY

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GENERAL ANATOMY, OR HISTOLOGY.

GENERAL ANATOMY, or as it is now more commonly termed HISTOLOGY, is that branch of Anatomy which treats of the structure of the textures. As has already been explained (see Introduction in Vol. I.), the body of every one of the higher animals is made up of organs adapted for the performance of its several functions, and these organs are themselves composed of various tissues or textures. In order that the structure of any organ or part of the body should be understood, it is necessary to study, both together and separately, the several tissues of which it is composed, in order to ascertain their composition and the manner in which they are combined to constitute the organ or part in question. This is chiefly effected by minute dissociations and thin sections, which are observed with the aid of the microscope, and hence the terms "Minute Anatomy" and "Microscopic Anatomy" are also applied to this branch of the science. It is found that when the body is thus dissected or analyzed by the aid of the microscope, that the number of distinct tissues which are met with is comparatively small, and some of these again, although at first sight to all appearance distinct, yet have so much in common in their structure and origin one with another (forms of transition also being met with between them), that the number becomes still further reduced. The elementary tissues which are generally enumerated are as follows:—

Epithelium or epithelial tissue.
Connective tissue with its varieties, including adipose tissue.
Cartilage and its varieties.
Bone or osseous tissue.
Muscular tissue.
Nervous tissue.

The elements which are met with suspended in the fluids of the body, such as the corpuscles in the blood, are also enumerated amongst the elementary tissues. So that we may add to the above list:—

Blood- and lymph-corpuscles.

Many of the organs are formed wholly of a single one of these elementary tissues, or with a comparatively slight intermixture of others. Thus the muscles are made up almost entirely of muscular tissue, with but a small intermixture of connective tissue, blood-vessels and nerves: and the same is the case with the bones; whilst the cartilages are composed wholly of the tissue of the same name. On the other hand, there are certain organs or parts of the body not in themselves distinguished by the preponderance of any special tissue, but compounded of two or more

in varying proportion, which it is nevertheless convenient to describe along with the elementary tissues, on account of their wide distribution in the body, and their uniformity of structure in different parts. These are :—

Blood-vessels.
Lymphatic vessels.
Lymphatic glands and bodies of like structure.
Serous membranes.
Synovial membranes.
Secreting glands.
Mucous membranes.
Integument.

Every texture taken as a whole was viewed by Bichat (Anatomie générale, 1801) as constituting a peculiar system, presenting throughout its whole extent in the body characters either the same, or modified only so far as its local connections and uses render necessary; he accordingly used the term "organic systems" to designate the textures taken in this point of view. Of the organic systems above enumerated some are found in nearly every organ; such is the case with the connective tissue, which serves as a binding material to hold together the other tissues which go to form an organ; the vessels, which convey fluids for the nutrition of the other textures, and the nerves, which establish a mutual dependence among different organs. These were named by Bichat the "general systems," to distinguish them from others such as the cartilaginous and osseous, which being confined to a limited number or to a particular class of organs, he named "particular systems."

Structural elements.—When any tissue is separated by the aid of the microscope into the simplest parts which possess assignable form, such parts are termed the structural elements of the tissue. In almost every tissue, some at least of these structural elements retain to a certain extent the characters of the elementary corpuscles of which the whole body is originally composed. These structural elements are named the "cells" of the tissue. Others again lose for the most part those characters, and becoming elongated and modified in structure, are termed the fibres of the tissue, whilst in other cases, fibres are formed not from the cells but between them. Except the epithelium, all the tissues have fibres as characteristic structural elements, and some, as the connective tissue, fibres of more than one kind. But structurally and chemically as well as functionally, the fibres of the several tissues differ widely from one another.

Intercellular substance.—In addition to these separable structural elements, many of the tissues are composed of a homogeneous matrix or ground substance, in which the structural elements are imbedded. This matrix may exist in considerable quantity, as in some varieties of connective tissue, or on the other hand it may be almost imperceptible in amount, serving merely as a cementing material to connect together the individual tissue-elements, as in epithelium. From its softness, clearness and homogeneity, this ground substance is often apt to escape observation, but its existence may always be rendered evident in consequence of the property it exhibits of combining with salts of silver, a brown deposit of metallic silver occurring in it on subsequent exposure to the light (v. Recklinghausen).

Since all the animal tissues however diversified they may appear, originate as collections of the elementary corpuscles or cells above spoken of, and since these cells remain, many of them, as constituent elements of the formed tissue, we must first of all consider minutely what it is that constitutes an animal cell, what is its structure, its chemical composition, its physical and vital properties, and how and from what the cells of the animal body are developed.

THE ANIMAL CELL.

A typical animal cell is a corpuscle of microscopic dimensions, the cells of the human body seldom exceeding $\frac{1}{300}$th of an inch in diameter, and many being as small as one-tenth of this, or even less. But whether small or large, every typical cell consists of two distinct parts: of the main substance of the cell, which has received the name of *protoplasm* (fig. 1, *p*), and of a minute vesicular structure, generally placed near the centre of the cell, and termed its *nucleus* (*n*).

Fig. 1.

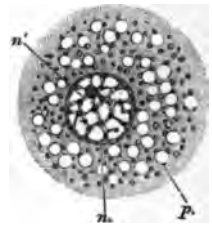

Fig. 1.—DIAGRAM OF AN ANIMAL CELL MUCH MAGNIFIED. (E.A.S.)

p, protoplasm, with vacuoles and granules; *n*, nucleus, with intranuclear network and nucleolus (*n'*).

THE PROTOPLASM OF THE CELL.

The substance to which the term protoplasm has been applied is, in its chemical nature, similar to albumen, being mainly formed of proteid substance. It is characterized by its affinity for certain staining fluids, such as solutions of carmine and hæmatoxylin. Although normally containing a relatively large amount of water combined in its substance, and thereby sharing many of the physical properties of water, it is not miscible with that fluid whilst in the living condition. Protoplasm usually appears to consist of two distinct portions; namely, of a clear, homogeneous semi-fluid material, which is in all probability the essential substance: and of minute granules or particles which are embedded in the hyaline substance, and which by their presence give to the protoplasm a granular appearance. These particles, although in most cells constantly present, are in all probability not essential constituents, but are rather to be regarded in the light of adventitious matter, which has either been formed in the protoplasm itself, or has been taken into it from without. For it is often the case that one part of the substance of a cell is entirely free from granules, whilst other parts may be crowded with them, and it is found, that in such instances the clear non-granular substance is capable of manifesting all the phenomena which are characteristic of protoplasm. Further, when the particles in question are larger and more distinct, it may often be demonstrated that they are different in chemical constitution from the substance in which they are embedded.

In addition to the more solid particles above mentioned, globules of watery fluid are also frequently met with. These refract the light less strongly than the protoplasm itself, and look like clear spaces in it: hence they have been termed *vacuoles*. There may be one, two, or a greater number of such vacuoles in a cell, and in some cases, the protoplasm is filled with them, or occupied by a large space formed by their confluence. This, as is especially evident in vegetable cells, causes the

cell-substance to assume a reticulated aspect. But where vacuoles are accumulated within it to a great extent, it is generally found that the protoplasm no longer exhibits certain characteristic properties, especially that of amœboid movement, presently to be described. Vacuoles are often absent altogether from a cell, and when present, appear and disappear and may become shifted in position from time to time.

What has been above described as the essential part of the protoplasm may itself exhibit a separation into two kinds of substance. For example, in many cells the protoplasm (whether or not granular) may undergo a differentiation into minute striæ, or fibrils, and clear intermediate substance, and in these cases there is reason to regard the fibrils as perhaps the more important part of the protoplasm. This is the case with the cell-substance in the epithelium cells of many secreting glands or of their ducts (fig. 2, *str*), and with the

Fig. 2.

Fig. 2.—STRIATED EPITHELIUM CELL, FROM THE DUCT OF A SALIVARY GLAND; HIGHLY MAGNIFIED. SEMIDIAGRAMMATIC. (E.A.S.).

gr, granular protoplasm ; *str*, striæ ; *n*, nucleus.

Fig. 3.

Fig. 4.

Fig. 3.—A CARTILAGE CELL OF THE SALAMANDER, SHOWING FINE FILAMENTS IN THE PROTOPLASM (Flemming).

Fig. 4.—DIAGRAM OF AN ANIMAL CELL (WITH TWO NUCLEI). (Klein.)

substance of nerve-cells, and Flemming and Schleicher describe the protoplasm of the cells of cartilage as consisting of a homogeneous fluid in which fine particles and minute fibrils are suspended (fig. 3).

This differentiation of the protoplasm in the form of fibrils would appear to be of much more general occurrence than is commonly supposed. According to the observations of Heitzmann, Fromann, Klein, and others, the protoplasmic substance of a cell is to be regarded as composed of a fine network or sponge-work, with a more fluid material in its interstices, the granules which are seen in protoplasm being for the most part the optical sections of some of the fibrils (fig. 4). At the same time it is admitted that true granules may also occur in the interstitial fluid, and in gland cells the products of secretion may here become accumulated. Putting the same idea in somewhat different words, such protoplasm may be described as being highly vacuolated ; the substances found in it (granules, materials of secretion) accumulating in its vacuoles.

Protoplasm seems to be weakly alkaline or neutral in reaction, although some of the lower organisms, blue litmus granules, which had been

taken into the interior of their protoplasm, were observed by Engelmann after a time to become red. This may, however, have been due to a formation of acid around the granules analogous to that which occurs in gastric digestion in the higher animals.

In conjunction with Mr. F. Eckstein, I have made a number of observations upon the white corpuscles of the blood in the same manner, and always found the blue litmus granules which were taken in by the corpuscle to remain unchanged in colour

That the protoplasm of a cell is elastic may be inferred from the manner in which a layer of cells is found to adapt itself to rapid and considerable alterations in the area which it covers; this is the case for instance with the layer of cells which lines the bladder, and with that which covers the outer surface of the lungs.

Contractility of protoplasm.—The most striking and important of the phenomena which are exhibited by cell-protoplasm are those which are due to its possessing the property of contractility. By this is meant the faculty of becoming diminished in diameter in any one direction, and proportionately increased or bulged out in other directions. This property of contractility which protoplasm possesses is shared by, or rather perhaps has become transferred to, other forms of living substance, not generally regarded as purely protoplasmic in nature; namely, vibratile cilia and muscular tissue. But in these the power of diminution is confined to one part or direction only, whereas in unaltered protoplasm the property is possessed by all parts, and is capable of being exerted in any direction. The following are the phenomena exhibited by protoplasm which can be referred to the possession of this property:

1. *Amœboid movement.*—As was first shown by Rosenhof, in 1755, the Proteus animalcule or Amœba, which is composed almost entirely of a mass of protoplasm, exhibits when observed under the microscope

Fig. 5.

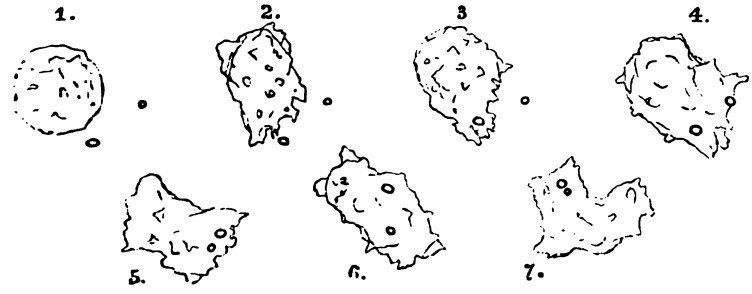

Fig. 5.—Changes of form of a white corpuscle of newt's blood, sketched at intervals of a few minutes. The figures show also the intussusception of two small granules, and the changes of position which these underwent within the corpuscle. (E.A.S.)

the most remarkable spontaneous changes of form; protruding, first on one side then on the other or even at two or more places simultaneously, portions of its protoplasm (pseudopodia), which may be again immediately withdrawn. On the other hand, any one of these projections may remain

protruded, and the substance of the protoplasmic body drawn towards it, so that in this way the amœba is moved about from place to place. Since these and similar changes of form and place of a protoplasmic organism were first distinctly observed and can still be best studied in the amœba, they are aptly termed amœboid. In the higher animals they are most plainly to be seen in the white blood-corpuscle (fig. 5) (where they were first detected by Wharton Jones,) but it is probable that they are exhibited to a slight degree by almost all animal cells in the young state.

2. *Streaming movement of the granules.*—This phenomenon can be seen to occur both in cells which are stationary, and in those which are exhibiting the amœboid movements just described. It consists in the slow motion in definite courses in the protoplasm of the granules which are suspended in that substance. There can be little doubt that the granules are themselves carried along by and swim in the moving protoplasm itself, although in consequence of its homogeneity the currents in it are only indicated by the suspended granules. The currents may not only pass in different directions in the main substance of the protoplasm, but they may also extend along its protrusions, when these exist, and it occasionally happens that there may be present in one and the same protrusion both an outgoing and an incoming stream.

These streaming movements have been longest known in the protoplasm of vegetable cells (Vallisneria, Chara, Tradescantia, &c.), but they are very strikingly manifested in the protoplasmic substance of the lower animal organisms, and there is reason to believe that they occur in many of the fixed cells of the tissues of the higher animals, although here much more difficult of detection. In the white corpuscles of the blood the granules in the protoplasm are seen to stream into the processes, which when first protruded are generally free from granules; but in this case the flow of particles may perhaps be caused in a different way from that in the other instances above given.

3. *Intussusception of foreign particles.*—When any minute foreign particle comes in contact with the protoplasmic substance, the particle is apt to adhere to it. But what is more remarkable, the particle does not remain in contact with the external surface; it becomes on the contrary enwrapped by processes of the protoplasm, and then withdrawn gradually into the interior, where it may remain for some time without change, being moved about by any currents which exist in the cell, and carried along by the changes of place which the cell undergoes (see fig. 5). Eventually such foreign particles may be extruded again. If, on the other hand, the particle is of considerable size as compared with the protoplasm with which it comes in contact, the latter extends around and over it so as to envelope it more or less completely. This phenomenon of intussusception seems thus to be partly dependent upon amœboid movement, and partly upon the production of currents in the protoplasm.

The protoplasm of ordinary vegetable cells being for the most part enclosed in a continuous cell-wall, instead of being naked like that of a typical animal cell, cannot be protruded in the shape of pseudopodia beyond that wall nor does it for the same reason exhibit the phenomenon of intussusception just described. But it is, nevertheless, as before mentioned, capable of active streaming movements, which are influenced by the same conditions (heat, electricity, and the like) as are the movements of animal cells.

Conditions influencing the contractile manifestations of protoplasm.—All these several manifestations of contractility, are influenced in the same manner by similar external conditions. Thus it is found that variations of temperature have a marked effect upon all. In warm-blooded animals the phenomena cease altogether to be exhibited, if the protoplasm which is under observation is cooled to below a temperature of about 10° C, although they will be resumed on warming the preparation again, and this even if it has been cooled to 0° C., or even a little lower. And when warmed gradually, it is found that they become more and more active as the temperature rises, attaining a maximum of activity a few degrees above the natural temperature of the body, although if maintained at an abnormally high temperature, the movements are not long continued. A temperature a little above this maximum, rapidly kills protoplasm, producing a stiffness or coagulation in it (heat-rigor), which is preceded by a general contraction. From the condition of rigor the protoplasm cannot be recovered.

The contractility of protoplasm is dependent upon supply of oxygen. If this be withheld, the movements will it is true proceed for a time as usual, but this is because protoplasm like other forms of contractile substance, such as muscle, has the power of storing away and using oxygen in some form of combination. For it is found that the active manifestations will not proceed indefinitely in the absence of oxygen, but cease after a time, to be renewed only on the accession of fresh oxygen.

Many reagents in solution influence the activity of protoplasm. Some of these act by adding to or subtracting from the water which it contains. As a general rule the imbibition of water by the protoplasm, accelerates its activity up to a certain point varying according to the source of the protoplasm which is under observation (Thoma), but beyond that point addition of water produces a destructive effect. A comparatively slight amount of desiccation, is, so far at least as regards the protoplasm of the higher animals, destructive of vitality, but this statement does not hold good for the protoplasm of many of the lower animal and plant organisms.

Amongst reagents acids, although very weak (even carbonic acid), stop the contractile manifestations, alkalies, on the other hand, if sufficiently dilute, increase at first their activity. They are stopped by chloroform and ether, but may be again resumed on the removal of those vapours. Some poisons (e.g. veratria) rapidly arrest the movements in question.

Effect of electrical and other stimuli upon protoplasm.—The effect of electrical stimulation upon protoplasm which is exhibiting either amœboid or streaming movement is, if sufficiently strong, to cause an immediate cessation of those movements, accompanied by a withdrawal into the main substance of any processes that may have been protruded. If the stimulation be intermitted, the movements will recommence, provided the shock has not been so severe as to injure the living substance.

Abrupt changes of temperature, and mechanical stimulation such as is produced by sudden pressure or harsh contact act in a similar manner.

These effects are probably to be explained by supposing that the stimulation produces a contraction of the substance in every possible direction, for the result is that the cell subjected to stimulation, assumes, if it be capable of doing so, the spherical form. Whether there is any actual diminution in volume accompanied by expression of fluid must remain undetermined.

Of chemical and other changes which occur in the protoplasm of cells.—The protoplasm of a cell may become variously altered in chemical constitution, all such changes tending to diminish the original activity of the cell and to fit it for a special function. An alteration often met within older cells is the conversion of the outer portion of the protoplasm into a comparatively hard layer, which constitutes an investment for the remainder, and in this way approximates the cell more to the vegetable type. Such a transformation is met with in a high degree in the stratified epithelia, in which the cells of the uppermost layers become almost entirely transformed into dense horny scales.

Another change which is apt to occur is the deposition within the cell of various chemical principles, which are either derived directly from the plasma of the blood, in which in such cases they pre-exist, or are elaborated by the cell itself from some other constituent of that fluid. Examples of these changes are to be found in the deposit of fat (fig. 7, *f*) and pigment, and of the peculiar constituents of certain secretions within the cells of the tissue or gland producing them (see fig. 6).

Fig. 6.

Fig. 6.—CRYSTALS OF URIC ACID IN CELLS, FROM THE RENAL ORGAN OF A MOLLUSC. (Boll.)

In the two left-hand figures, the crystals are enclosed in vacuoles.

Sometimes changes of the same kind are connected with the production of new structures in a cell, as in the formation of red blood-corpuscles within the cells of connective tissue (fig. 7, *h*, *h*).

Fig. 7.

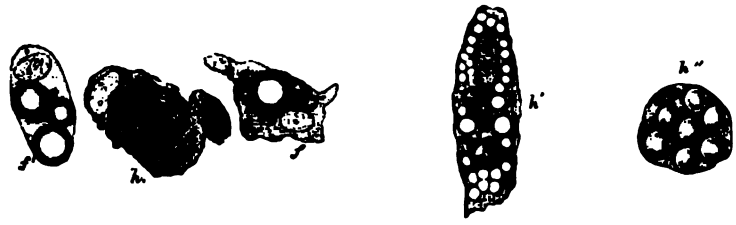

Fig. 7.—DEPOSIT OF FAT AND FORMATION OF RED BLOOD CORPUSCLES WITHIN CONNECTIVE TISSUE CELLS. (E.A.S.)

f, *f*, cells in which fat globules are being deposited; *h*, *h*, cells in which red blood corpuscles are becoming formed.

THE NUCLEUS OF THE CELL.

The nucleus (fig. 1, *n*) is a minute vesicular body, placed generally near the centre of the cell and embedded therefore in the protoplasm. In form it is round or oval in most cases, but it may be irregular in shape. Its size relatively to that of the cell varies much in different instances, for sometimes there is so small an amount of protoplasm that the nucleus appears to occupy nearly the whole cell. This is the case for example with many of the cells which are met with in lymphatic glands, and the small nerve-cells which are found in the cerebellum and elsewhere. On other hand, the protoplasm of the cell, whether altered as in the

superficial layers of stratified epithelium, or unaltered as in many of the white corpuscles of the blood, may much exceed the nucleus in bulk. In absolute size, the nucleus does not exhibit any very considerable variation in different cells of the same animal. There are, however, some notable exceptions; thus the nucleus is absolutely much larger in the ovum or egg-cell and in many nerve-cells than it is in other cells of the body.

Structure of the nucleus.—In the typical resting condition the nucleus is always bounded by a well defined wall, which encloses the nuclear contents. These are of two kinds, formed and amorphous. To the latter the term *nuclear fluid* is sometimes applied, and the former is sometimes named *nucleo-plasm* or *karyo-plasm;* this term being used to include also the substance which forms the wall of the nucleus. But it is by no means certain that the homogeneous amorphous substance which occupies the interstices of the nucleo-plasm is of a fluid nature, so that it might probably be better to term it the *nuclear matrix.* The name nucleo-plasm, on the other hand, although not altogether without objection, is probably as convenient as any other that has been proposed.

The nucleo-plasm often takes the form of one or more strongly refracting granules or globules, which are named *nucleoli.* The nucleoli may be suspended, isolated, in the nuclear matrix, or they may be connected with one another, if they are more than one, and with the nuclear wall by a network of fine filaments, which also form part of the nucleo-plasm (fig. 8). There is little doubt that these various parts of the nucleus are capable of undergoing spontaneous changes in relative amount and form. Thus it is found that when treated with hæmatoxylin the nuclear matrix has in some cases a considerable affinity for that colouring matter, in others very much less or none at all; the latter when the nucleoplasmic fibres are much increased in amount, as is the case when the nucleus is about to undergo division. From this it is inferred that a substance readily becoming stained by hæmatoxylin was in the first instance suspended uniformly in the nuclear matrix and has subsequently become shed out, so as to increase the bulk of the already existing nucleoplasmic fibres.

Fig. 8.

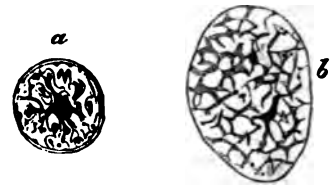

Fig. 8.—Cell-nuclei, exhibiting the reticulate appearance of the nucleo-plasm. (Flemming.)

a, nucleus of liver-cell (carp); *b*, nucleus of a connective tissue cell.

We have also observations showing that spontaneous changes of form may occur in nuclei. Thus both Flemming and Stricker have noticed, in preparations of blood, nuclei, which had been set free by rupture of the corpuscles to which they belonged, exhibiting spontaneous changes of form, and Klein has made a similar observation upon the large nuclei of the glands in the skin of the triton. Within the living epithelium-cells of the tail of salamander larvæ, Flemming also noticed alterations taking place in the outline of the nuclei. Furthermore, several observers have noticed and described spontaneous changes of form in nucleoli, which they have compared to the amœboid movements of protoplasm.

There are still some considerable differences of opinion regarding the structure of the nucleus. Thus, while Flemming looks upon the nucleoli as perfectly distinct from the network of nucleo-plasm which may be present with them, Klein is inclined to regard them as nothing but the optical expression of some of the filaments of the intra-nuclear network which, passing in the direction of the axis of vision, appear as dots instead of fibres, or at least as enlargements merely of the nodes of that network, and composed of the same substance.

Eimer describes a more complicated arrangement as existing in many nuclei in the form of a clear "hyaloid" zone, encircling the nucleolus, and bounded by a circlet of granules, which are united with the nucleolus by fine radial filaments. It is difficult to avoid thinking that the appearances described by Eimer must be mainly an optical effect produced by reflexion of light from the sides of the nucleolus.

Chemical nature of the nucleus.— From the affinity which, in common with protoplasm, it possesses for certain colouring matters, as well as for other reasons, the nucleus has been supposed by some eminent histologists (and notably by Lionel Beale, who has applied the term "germinal matter" to both) to be identical in nature with that substance. Its behaviour, however, with many reagents is altogether different; and in general it may be said that it offers greater resistance to their action than the substance which surrounds it.

Thus dilute acids and digestive fluids, which destroy protoplasm, only render the nucleus more distinct. Moreover, as we have seen, it stains much more intensely with hæmatoxylin and many other reagents, than does protoplasm, and, on the other hand, it remains in some cases unstained by reagents which colour protoplasm intensely, for example, solution of chloride of gold. So that chemically at least there is no doubt a considerable difference between the nucleus and the protoplasm. Still when we regard the spontaneous changes which are manifested by both, and especially the important part which the nucleus plays in the division of the cell, as will be immediately described, there is much in favour of the view which regards the nucleus as a portion of the living substance, which is set aside, altered it is true in chemical nature, to preside over the multiplication and reproduction of the cell; and in favour of this there are observations which show that under certain circumstances, the nucleus may enlarge at the expense of the protoplasm, even to the extent of absorbing the greater part of the latter, so that the whole cell is little else than nucleus; and indeed, this relative increase of size of the nucleus seems to be a change which constantly precedes the phenomena of cell-division.

The observations on the spontaneous movements of the protoplasm of the lower animal organisms by Dujardin, Meyer, Huxley, M. Schultze, J. Müller, Siebold, and others, and of that of the white corpuscles of the blood and other cells by Wharton Jones, Kölliker, Virchow, Kühne, and M. Schultze led eventually, as has been pointed out by Stricker ("Handbook of Histology," p. 2), to a clearer understanding of the nature of cells and its formulation by *E. Brücke* ("Die Elementarorganismen" Wiener Sitzungsb. 1861) and *M. Schultze* ("Ueber Muskelkörperchen und das was man eine Zelle zu nennen habe" Reichert and Du Bois-Reymond's Archiv, 1861); by whom it was demonstrated that the cell membrane, which entered materially into the conception of the structure of the animal cell as understood by its discoverer Schwann, and his immediate successors, is in no way an essential part of it. It should be added, however, that the existence of animal cells destitute of a cell envelope was clearly recognized by Schwann himself ("Microscopische Untersuchungen," 1839, p. 209). The fundamental importance of the protoplasm and [illegible]us (germinal matter) as distinguished from the cell-membrane and other

products of the protoplasm (formed material) was independently asserted by *Lionel Beale* ("On the Structure of the Simple Tissues of the Human Body," 1861).

MULTIPLICATION OF CELLS.

Cells multiply by division, the process being as a rule binary, each cell dividing into two other cells, these again into two, and so on. The division of a cell is preceded and accompanied by certain changes in the form and constitution of the nucleus; with comparatively unimportant modifications, these changes are similar both in the vegetable and in the animal kingdom. Our knowledge of them was originally due to the researches of Strasburger, made chiefly upon the vegetable cell, but was soon extended to the animal cell by numerous observers, amongst whom may be mentioned in the first instance Eberth, Mayzel, and Flemming. It is the account given by the last-named observer which will be adhered to in the following description of the phenomena which accompany cell-division.

The mode of cell division which is characterised by the changes in the nucleus here to be described is sometimes known as "indirect cell-division," to distinguish it from the division of a cell by simple constriction of its nucleus and protoplasm into two (or more) parts ("direct cell multiplication,") which until recently was thought to be the universal method, although now believed to occur rarely, if at all.

When a cell is about to divide, its nucleus, which may previously have presented the usual structure characteristic of resting cells—consisting, namely, of a vesicle containing a network of nucleoplasmic

Fig. 9.

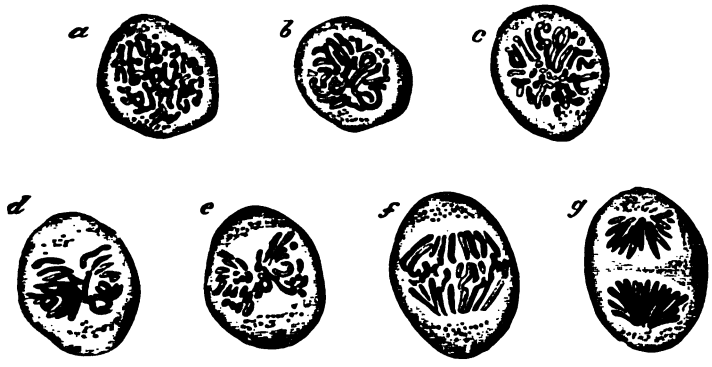

Fig. 9.—STAGES IN THE DIVISION OF THE NUCLEUS OF A LIVING EPITHELIUM CELL IN THE EPIDERMIS OF A SALAMANDER-LARVA. (Flemming.)

a, cell showing the nucleus transformed into a mass of contorted filaments (corresponds to *b* and *c* of fig. 10); *b*, the nuclear filaments have become fewer and more united, and begin to assume a converging arrangement (compare *d*, *e*, *f* of next figure); *c*, stellate form (compare *g*, fig. 10); *d*, *e*, hourglass contraction of the nucleus which gradually passes off and the form *c* is resumed. This may occur more than once: eventually the filaments accumulate in a direction parallel to one another near the centre of the cell, and then gradually separate into two sets as shown in *f* (*i*, *j*, *k* in fig. 10). These as they retire towards the poles gradually resume the stellate form *g* (*l*, fig. 10). The time occupied whilst the stages above represented were passed through was about three hours.

fibres which stain darkly with carmine, and a nuclear matrix staining less deeply (fig. 10, *a*)—becomes transformed in the following way. In

the first place it appears rather larger and less defined, and its interior is found to contain a close interlacement or skein of contorted filaments of nucleoplasm (fig. 10, *b*, *c*), to which the nucleoli and intranuclear network have given place, whilst the nuclear matrix has lost its affinity for staining fluids. Meanwhile the body of the cell has become, if

Fig. 10.

Fig. 10.—EPITHELIUM CELLS OF SALAMANDER-LARVA IN DIFFERENT STAGES OF DIVISION. THE CELLS WERE HARDENED IN PICRIC OR CHROMIC ACID, AND STAINED WITH HÆMATOXYLIN OR SAFRANIN. HIGHLY MAGNIFIED. (Flemming.)

a, resting cell, showing parts of the nuclear network which is stained, as is (slightly) the nuclear matrix; *b*, first stage of division, nucleus transformed into a mass of closely contorted filaments; *c*, second stage, filaments larger and less closely arranged: in this and all the other figures except *a* the nuclear matrix is clear; *d* (rather more magnified than the rest), filaments larger and becoming arranged in loops: this is more evident in *e*, where they collectively have a rosette-like appearance enclosing a central clear space; *f*, filaments converging towards the centre, the nucleus passing into the stellate phase, *g*, in which the peripheral loops of the rosette have become severed; *h*, longitudinal splitting of the filaments; *i*, equatorial stage of Flemming; the nuclear filaments parallel with one another in the centre of the cell; *j*, commencement of a separation into two sets; *k*, separation more advanced; *l*, stellate phase of daughter-nuclei; *m*, rosette phase of the latter; *n*, filaments becoming again irregularly contorted; *o*, *p*, gradual passage of daughter-nuclei into condition of rest (network, *q*). The division of the protoplasm is seen to begin in the stage represented by *m* and to be rapidly completed (at *n*).

previously flattened or elongated, more rounded in form, and it may often be observed that the granules which are present in the protoplasm become arranged into two groups placed on each side of the cell (fig. 9, *a*).

This condition of the nucleus passes gradually into one in which the filaments of nucleoplasm are less fine and also less contorted, whilst they are rather more separated from one another, as if the finer filaments had shortened themselves, and in shortening had become proportionately thicker and further apart (fig. 9, *b* ; fig. 10, *d*).

It is difficult to say if there is really only one filament twisted in a complicated manner on itself, or if there are several intertwining filaments. But whether originally only one or several, in the next stage, if the latter is the case, their ends join so that there is to all appearance only one long nucleoplasmic fibre which becomes arranged in such a manner as to form a rosette-like structure, looping alternately in and out from a central space which is left clear (fig. 10, *e*). Long before this the membrane of the nucleus has disappeared as such, apparently being absorbed into the skein-like system of nucleoplasmic fibres, but a zone of clear substance, perhaps derived from the nuclear matrix, separates that system of fibres from the protoplasm of the cell.

The fibre or fibres next separate into portions of equal length, (the separation generally occurring in the rosette stage, although it may happen earlier). The change often begins at those parts of the rosette which are to become the poles of the nucleus. The peripheral loops of the rosette become broken through, whilst the central loops tend inwards and converge towards the centre of the rosette, so that a star is the result (fig. 9, *c*; fig. 10, *f*, *g*). Occasionally the convergence is towards two points instead of one, so that a double star is produced ; the division of the nucleus being thus early indicated. This astral or amphiastral condition persists for some little time, but not always without alteration, for the aster is sometimes observed to undergo changes of form and size, becoming alternately more flattened, and again more rounded, and this so rhythmically as to have suggested the change being spoken of as the systole and diastole of the star.

The fibres which form the rays of the star often become split longitudinally, the cleavage extending gradually from their free end towards their centre, the result being that they are both more numerous and finer (fig. 10, *g*, *h*).

In the next phase, which is termed by Flemming the equatorial stage of division (fig. 9, *f*; fig. 10, *i*, *j*), the V-shaped nucleoplasmic fibres have become collected, parallel to one another, in the middle, often leaving a space clear at either end ; these spaces being opposite to the poles of the nucleus. Collectively the fibres form a somewhat barrel-shaped system at this stage : in each fibre the angle of the V is directed towards one of the poles of the nucleus, whilst the limbs either interlace or abut against one another at the equator. Presently the fibres of the system are seen to be separating into two groups (fig. 10, *k*), leaving a clear space in the plane of the equator, and the two groups, gradually become more distinct from one another, travel towards the poles of the nucleus.

From the two groups of fibres thus separated the nuclei of the two new cells become derived, and we may speak of them, therefore, as the nucleoplasmic fibres of the daughter-nuclei. The mode in which they resume the structure of ordinary nuclei is by a reversal of the phases which were exhibited by the mother-nucleus. Thus the nucleo-

plasmic fibres in each of the two daughter-nuclei take on first of all a stellate disposition (fig. 10, *l*), next the rays of the star become united in loops, so that the rosette condition is reproduced (fig. 10, *m*), then each rosette becomes a skein of contorted fibres (fig. 10, *n*, *o*) and finally the normal condition of a resting nucleus is attained with its nuclear membrane, and intranuclear network (fig. 10, *q*)

In addition to the nucleoplasmic fibres, the changes of which have been described above, other fibres may often be seen in the clear substance which occupies the ends of the mother nucleus in the equatorial phase, converging from the equator to the poles; and, when the daughter-nuclei have become separated, bridging across the interval between them (see fig. 11). These fibres do not, like the others, become stained with hæmatoxylin, and are hence termed "achromatic" by Flemming: they are much better marked in some cells than in others, and they probably exercise an important influence as guides, along which the movements of the other fibres take place. In the division of the ovum, and in the multiplication of the nuclei of vegetable cells the achromatic fibres are exceedingly prominent and form a spindle shaped system of a characteristic aspect and looking at first sight very different from those nuclei the division of which has just been

Fig. 11.

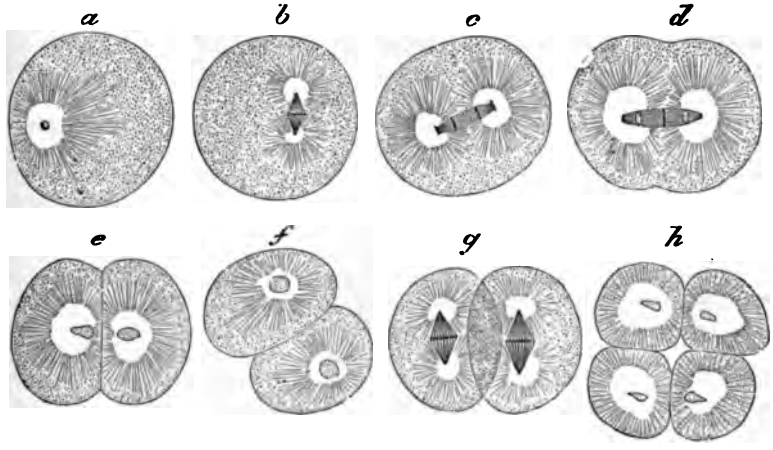

Fig. 11.—Stages in the division of the ovum or egg-cell of a worm. (Strasburger.)

a, resting state; *b*, nucleus transformed into a spindle-shaped system of fibres, which are provided with thickenings at the equator of the spindle; *c*, separation of equatorial thickenings into two parts which gradually travel towards the poles of the spindle and there become transformed into new (daughter) nuclei, whilst the protoplasm at the same time also separates into two parts (*d*, *e*, *f*); *g*, repetition of the division process, formation of spindles in daughter cells; *h*, result of the division of these. (The nuclear filaments shown in fig. 10 are here probably only represented by the thickenings at the equator of the spindle-shaped system, which is mainly formed by fine straight filaments, which stain far less with hæmatoxylin than the others, and on account probably of their less distinctness and want of colouration are not seen in the nuclei represented in fig. 10.)

described. But transitions which are met with indicate that the spindle and its transformations represent merely simplified modifications of the usual type, resulting it may be from the scanty amount of nucleoplasm or substance staining with hæmatoxylin, and the relatively large amount of achromatic material in those nuclei in which the spindle is prominent.

Meanwhile the protoplasm of the cell has begun to collect itself towards each of the two new nuclei. This often commences whilst the daughter-nuclei are yet in the stellate phase. By the time that they have arrived at the rosette stage, the protoplasm has usually divided into two equal halves (fig. 10, *m*), the process being generally accompanied by a constriction which extends in from the exterior, and is presumably effected by the powerful and equal attraction which is exerted upon it by the new nuclei.

In proof of some such influence, may be adduced numerous instances in which the granules of the protoplasm become arranged in lines converging towards the poles of the mother-nucleus, or towards the daughter-nuclei, thus producing an amphi-astral appearance in the cell. This is often very distinct in dividing ova (fig. 11).

The division of the cell is now complete. The two daughter-cells are of course each at first smaller than the mother-cell, but they soon grow, and the process may recommence and be repeated in them, and in this way cell-multiplication may be exceedingly rapid. The cells commonly become entirely separated ; in some tissues, however—cartilage, for instance—they may remain in proximity, producing thus groups of two or four newly-formed cells, which, in the case of that tissue, may at first be enclosed in a common cavity of the matrix : this process of multiplication has been styled "endogenous." But it is in all probability essentially the same as in the less solid tissues.

Fig. 12.

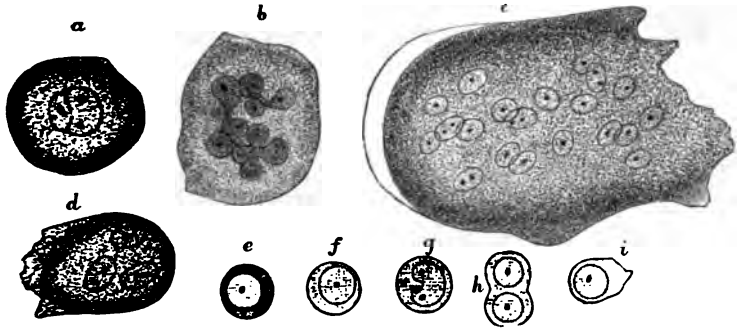

Fig. 12.—MULTINUCLEATED CELLS FROM THE MARROW. HIGHLY MAGNIFIED. (E.A.S.)

a, a large cell the nucleus of which appears to be partly divided into three by constrictions ; *b*, a cell the enlarged nucleus of which shows an appearance of being constricted into a number of smaller nuclei ; *c*, a so-called giant-cell with many nuclei ; *d*, a smaller cell with three nuclei ; *e*—*i*, other cells of the marrow.

Sometimes, a multiplication of nuclei within a cell occurs without immediate separation into new cells, as in the white corpuscles of the blood in which it is common to see two, three or even more nuclei ; in the large multinucleated cells which are found in the medullary cavities of bone, (fig. 12), and in the spermatic cells of the testis, the nuclei of which may undergo division a number of times prior to the separation of a part of the protoplasm around each. The division of the cell itself occurs in these cases by a portion of the protoplasm gathering around

each of the daughter-nuclei, and the original cell thus dividing into as many new cells as there are nuclei in it.

Instances have been observed out of the body in which the amœboid movements of the protoplasm seem to have been concerned in the cell-division, but this occurrence is seldom, and most likely accidental; indeed, it is found, as a general rule, that whilst cell-division is proceeding, the external manifestations of activity of cell-protoplasm cease almost entirely.

The following are the more important phases of change of the dividing nucleus put in tabular form (Flemming)* :—

Mother-nucleus.		*Daughter-nuclei.*
Network.	(State of rest).	Networks.
Skein.		Skeins.
(Rosette).		(Rosettes).
Aster.		Asters.

Equatorial grouping of fibres.

OF THE ORIGIN OF CELLS.

So far as is at present known, every cell in the animal body has been derived from a previously-existing cell. If we trace back the development of the cells of which the body is at one time entirely composed—the so-called *embyronic cells* (fig. 13),—we find that they are originally produced by the division of a single cell derived from the female parent, and termed the *ovum* or *egg-cell*.†

Fig. 13.

Fig. 13.—THREE CELLS FROM EARLY EMBRYO OF THE CAT. HIGHLY MAGNIFIED. (E.A.S.)

b, protoplasm ; *c*, nucleus with nucleolus. The lowermost cell has two nuclei.

Fig. 14.

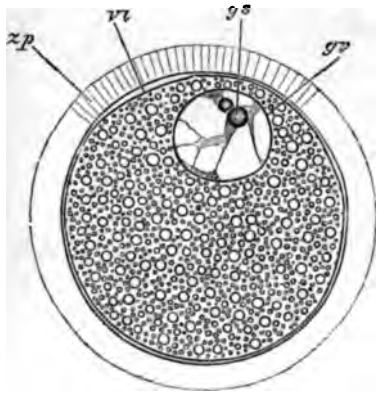

Fig 14.—OVUM OF THE CAT ; HIGHLY MAGNIFIED. SEMI-DIAGRAMMATIC. (E A.S.)

zp, zona pellucida ; *vt*, vitellus ; *gv*, germinal vesicle ; *gs*, germinal spot.

Cell-nature of the mammalian ovum.—The ovum (fig. 14), as it occurs in the female organ or ovary, is a large cell enclosed in a distinct envelope ; otherwise consisting like other animal cells of protoplasm and a nucleus.

* The term "karyokinesis" is sometimes applied collectively to the changes of a dividing nucleus.

† In the account which follows of the early changes which the ovum undergoes, leading to the production of the embryonic cells, no attempt is made to give a complete history of the early developmental processes, but the subject is merely alluded to in connexion with the relation which the egg-cell bears to other cells of the animal body. The full description of the processes in question will be found in the chapter on Embryology, at the end of this volume.

Special names have long been applied to these parts in the ovum. Thus the nucleus of the ovum is termed the *germinal vesicle* (*gv*), and the main collection of nucleoplasm within it—the nucleolus—is termed the *germinal spot* (*gs*); while the protoplasm of the cell has been named the *vitellus* or *yolk* (*vi*). Enclosing the whole is a thick radially striated structure, the *zona pellucida* (*zp*).

This egg-cell or germ-cell is not, at least in the higher animals, capable of undergoing complete cell-division, and thus initiating development, without first passing through certain changes which are not, it is believed, shared by ordinary cells. To these changes in the ovum the terms *maturation* and *fertilization* are applied, and their result is the production of the first embryonic cell.

The maturation of the ovum essentially consists in the extrusion of a portion of the nucleus or germinal vesicle, together with a small amount of the protoplasm or vitellus. This process of extrusion appears to be really a division of the cell into two very unequal portions, the larger of the two being still termed the ovum, the smaller, which may again divide into two, being termed a polar globule, or it might be better to term it an extrusion-globule. The following is the way in which this change becomes effected*:—Soon after the ovum leaves the ovary, or immediately before, its nucleus, which previously

Fig. 15.

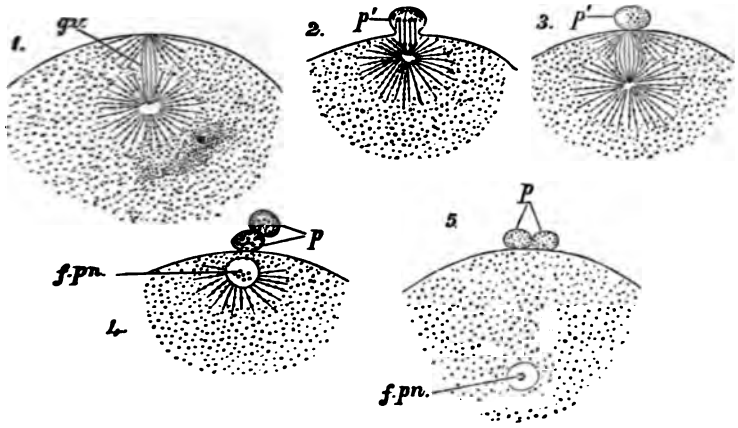

Fig. 15.—STAGES IN THE FORMATION OF THE POLAR GLOBULES IN THE OVUM OF A STAR-FISH (from Hertwig).

g.v, germinal vesicle transformed into a spindle-shaped system of fibres; *p'*, the first polar globule becoming extruded from the surface of the ovum; *p*, *p*, polar globules completely extruded; *f.pn*, female pronucleus.

presented the structure typical of the nucleus of a resting cell, shows indications of a change, and becomes transformed into a spindle-shaped system of fibres which is situated near the surface of the vitellus (fig. 15, *g.v*). Presently one pole of the spindle is protruded from the surface of the vitellus (*p'*) into a space (perivitelline space) between the zona pellucida and the vitellus, caused by a shrinking of the latter. In the next place the substance of the nucleoplasmic fibres gradually collects towards the poles of the spindle in much the same way

* The description which follows applies to the ovum of the star-fish as observed by Fol and Hertwig; but the researches of Ed. van Beneden indicate that similar phenomena attend the extrusion of the polar globules in the mammalian ovum, although on account of the difficulties of the observation all the phases have not as yet been seen.

as during the division of the nucleus in an ordinary cell, and two daughter-nuclei are thus formed, one remaining in the ovum, and the other, together with a very small amount of the vitellus, becoming free in the perivitelline space as a polar globule (fig. 15, 3, *p'*). This may again undergo division, or a second polar globule may be produced from the nucleus of the ovum in the same way as was the first. The nucleus of the ovum now moves again towards the centre, there to await the advent of the fertilizing agent. Since it is now somewhat different from an ordinary nucleus in its incapability to initiate the division of the cell without the access of a fertilizing agent, as well as in structure, no nucleoplasmic network being visible, it is no longer termed the nucleus, but the *female pro-nucleus* (fig. 15, 4, 5 *f.pn*).

Arrived at the condition above described, the ovum seems incapable of undergoing further change until it has received and blended with a portion of one of the male generative cells. The latter give off, in a manner which will be described when the male organs of generation are treated of, minute portions of their nuclei and protoplasm in the form of the so-called spermatozoa. These consist of an extremely minute particle of nucleoplasm termed the head, a small intermediate mass of protoplasm named the body or neck, and a long spontaneously vibratile filament, the tail, by the movements of which they

Fig. 16.

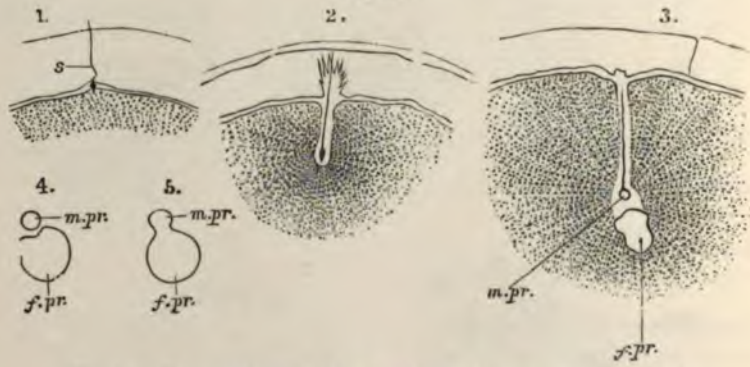

Fig. 16.—Fertilization of the ovum of an echinoderm (Selenka).

s, spermatozoon ; *m.pr*, male pronucleus ; *f.pr*, female pronucleus.

1. Accession of a spermatozoon to the periphery of the vitellus ; 2. Its penetration, and the radial disposition of the vitelline granules ; 3. Transformation of the head of the spermatozoon into the male pronucleus ; 4, 5. Blending of the male and female pronuclei.

are propelled, and thus assisted to reach the ovum. This accomplished, they pierce the zona pellucida, and the head of a spermatozoon, generally of only one, becomes buried in the periphery of the vitellus (fig. 16, 1). The imbedded head enlarges, and becomes transformed into a clear spheroidal body, the *male pro-nucleus*, which, as the lines of vitelline granules which converge towards it indicate, exerts a powerful influence upon the protoplasm of the ovum (2, 3). Soon it begins to move towards the female pro-nucleus, and reaching this the two become blended and a new nucleus is formed by their coalescence (4, 5). It is this nucleus, formed by the fusion of the male and female pro-nuclei, which initiates the division of the egg-cell and thus commences the development of the embryo.

Production of embryonic cells from the fertilized ovum, and their arrangement into layers.—Fertilization being completed, the ovum proceeds to divide into two daughter-cells (termed *segments* or *-tomeres*) in the same manner, and passing through the same phases,

as any other dividing cell. It is true that all the different forms of the nuclear fibres and the stages above described, in speaking of cell-division, have not been made out in the division of the egg-cell, but enough has been seen to warrant the assumption that the process is in the main the same. The result is, however, somewhat different, for in the mammalian ovum the two daughter-cells are not perfectly similar: one of them is larger, clearer, and, as the sequel shows, possessed of greater developmental activity than the other one, which is smaller and more granular. We may provisionally term the former the *ectomere* and the latter the *entomere* (fig. 17, *a*). The segmentation into two cells is soon followed by the division of each of these so that four are produced (fig. 17, *b*), and the process of multiplication being continued with more or less regularity a small solid mass of cells eventually results from the division

Fig. 17.

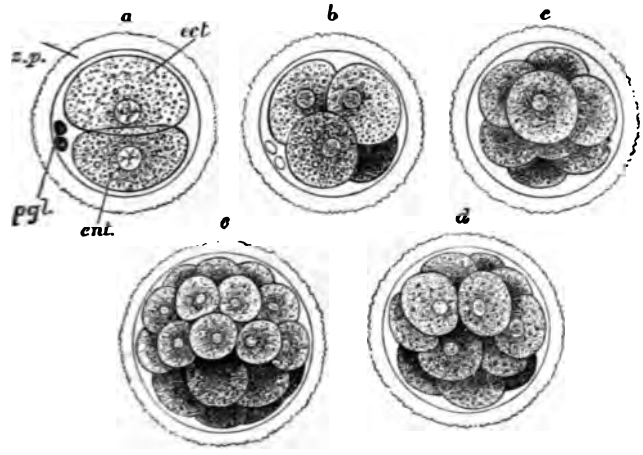

Fig. 17.—First stages of segmentation of a mammalian ovum: semi-diagrammatic (Drawn by Dr. Allen Thomson, after Ed. v. Beneden's description).

z.p., zona pellucida; *p.gl.*, polar globules; *ect.*, ectomere; *ent.*, entomere. *a*, division into two blastomeres; *b*, stage of four blastomeres; *c*, eight blastomeres, the ectomeres partially enclosing the entomeres; *d*, *e*, succeeding stages of segmentation showing the more rapid division of the ectomeres and the enclosure of the entomeres by them.

of the egg-cell (fig. 17, *e*, and fig. 18, *a*). Presently fluid tends to accumulate in the interior of the mass (fig. 18, *b*), transforming it into a hollow vesicle which is termed the *blastodermic vesicle* (fig. 18, *c*, *d*). The wall of this is formed by only a single layer of flattened cells (*ect.*), except at one part where there is a small patch of granular cells (*ent.*) constituting another but an imperfect layer, which, however, before long extends around the whole vesicle. A third or intermediate layer (derived from one or both the others) makes its appearance between the two which are first formed so that the blastoderm is finally tri-laminar. The outermost of the three blastodermic layers is termed the *ectoderm* or *epiblast*, the innermost, the *entoderm* or *hypoblast*, while the intermediate layer is the *mesoderm* or *mesoblast* (see fig. 20).

The result then of the division of the ovum is the production of

Fig. 18.

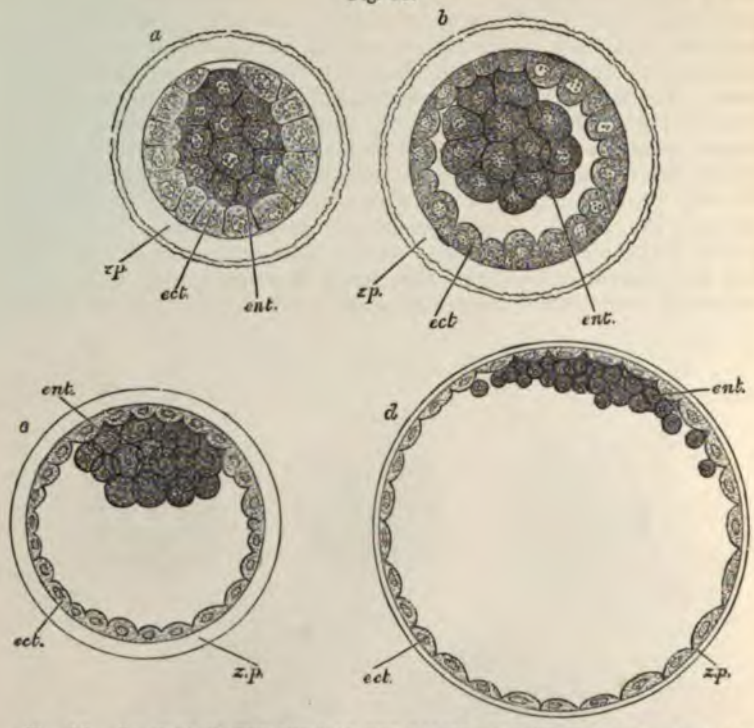

Fig. 18.— Sections of the ovum of the rabbit during the later stages of segmentation, showing the formation of the blastodermic vesicle (E. v. Beneden).

a, Section showing the enclosure of entomeres by ectomeres except at one spot—the blastopore; *b*, more advanced stage in which fluid is beginning to accumulate between entomeres and ectomeres, the former completely enclosed; *c*, the fluid has much increased, so that a large space separates entomeres from ectomeres except at one part; *d*, blastodermic vesicle, its wall formed of a layer of ectodermic cells, with a patch of entomeres adhering to it at one part; *z.p.*, *ect.*, *ent.*, as before.

A Fig. 19. *z. p.*

pr. Fig. 20.

Fig. 19.—A. Section through part of a bilaminar blastoderm of the cat (E.A.S.) *ect.*, *ent.*, ectoderm, entoderm; *z.p.*, thinned out zona pellucida.

—Section of trilaminar blastoderm of the rabbit (Kölliker). *ect.*, *ent.*, e; *mes.*, mesoderm continuous in middle (*pr.*) with ectoderm.

numerous cells (embryonic cells), which are arranged in the three definite layers above enumerated. From these embryonic cells and their descendants the various tissues of the body eventually become formed. This development of the tissues or "histogenesis" does not take place promiscuously, but there is a certain relation maintained between the several layers of the blastoderm, and certain tissues; that is to say, some tissues are always formed from cells belonging to one layer, others from cells belonging to another. The following is the relation, given in tabular form :—

Ectoderm or Epiblast	Nervous tissue. The epithelium of the sense organs. The epithelium of the central canal of the spinal cord and of the ventricles of the brain. The epithelium of the skin (epidermis). The epithelium of the mouth.
Entoderm or Hypoblast	The epithelium of the alimentary canal (except the mouth) and of the glands in connexion with it.
Mesoderm or Mesoblast	The renal epithelium. The epithelium of vessels and serous membranes. The connective tissues (including cartilage and bone). Muscular tissue.

OF THE NUTRITION AND GROWTH OF CELLS.

When a cell divides, the resulting cells, as we have seen, are smaller than the original cell; but they speedily grow, and each of the daughter-cells before long attains the size of the mother-cell. In order to enable cells thus to grow or increase in size, they are supplied with nutritive material, which, under ordinary circumstances is immediately derived from the plasma of the blood, which transudes through the coats of the small blood-vessels, and thus reaches the elements of the tissues. It is in all cases a necessary condition that this material of nutrition should be brought within reach of the spot where nutrition goes on, although it is not essential for this purpose that the vessels should actually pass into the tissue.

In the instance of cuticle and epithelium, no vessels enter the tissue, but the nutrient fluid which the subjacent vessels afford penetrates a certain way into the growing mass, and the cells continue to assimilate this fluid, and undergo their changes at a distance from, and independently of, the blood-vessels. In other non-vascular tissues, such as articular cartilage, the nutrient fluid is doubtless, in like manner, conveyed by imbibition through their mass, where it is then attracted and assimilated. The mode of nutrition of these and other non-vascular masses of tissue may be compared, indeed, to that which takes place throughout the entire organism in cellular plants, as well as in those simple kinds of animals in which no vessels have been detected. But even in the vascular tissues the conditions are not absolutely different; for although the vessels traverse the tissue, they do not penetrate into its structural elements. Thus the capillary vessels of muscle pass between and around its fibres, but do not penetrate their inclosing sheaths. The nutrient fluid, on exuding from the vessels, has here, therefore, as well as in the non-vascular tissues, to permeate the adjoining mass by transudation, in order to reach these elements, and yield new substance at every point where renovation is going on. The vessels of a tissue have, indeed, been not unaptly compared to the artificial channels of irrigation which distribute water over a field; just as the water penetrates and pervades the soil which lies between the intersecting streamlets, and thus reaches the growing plants, so the nutritious fluid, escaping through the coats of the blood-vessels, must permeate the interme-

diate mass of tissue which lies in the meshes of even the finest vascular network. The quantity of fluid supplied, and the distance it has to penetrate beyond the vessels, will vary according to the proportion which the latter bear to the mass requiring to be nourished.

By its growth taking place more in one direction than another, a cell becomes modified in shape. Of course, if a cell, originally spherical, grows equally in all directions, the spherical form is maintained, except in those cases where, by mutual compression the cells acquire flattened sides and a polyhedral shape. If the cell grows out very much more in one direction than in others, a fibre may be formed, as in the production of nerve-fibres; or, if a cell thus produced becomes hollowed out and united with other similar cells, a vessel may result, as in the production of blood-vessels. By the growth of a cell at several different points or by its retraction between certain points, a stellate form is produced; and, indeed, innumerable instances might be given of modifications in the shape of cells produced by inequalities in growth.

One of the modifications in shape produced by compression has just been referred to. Another instance is seen in those cases in which, by the continual division and growth of deeper lying cells, other cells, which are placed more superficially, become flattened out and forced towards the surface, as happens in the case of the stratified epithelia.

Waste of the tissues.—The tissues and organs of the animal body, when once employed in the exercise of their functions, are subject to continual loss of material, which is restored by nutrition. This waste or consumption of matter, with which in all cases the use of a part is attended, takes place in different modes and degrees in different structures. Thus in the cuticle the decayed parts are thrown off at the free surface; in the vascular tissues, on the other hand, the old or effete matter must be first reduced to a liquid state, then find its way into the blood-vessels, or lymphatics, along with the residual part of the nutritive plasma, and be by them carried off.

Regeneration.—When a part of a texture has been lost or removed, the loss may be repaired by regeneration of new substance of the same kind; but the extent to which this restoration is possible is very different in different textures. The special circumstances of the regenerative process in each tissue will be considered hereafter; but we may here state generally, that, as far as is known, the reproduction of a texture is effected in the same manner as its original formation.

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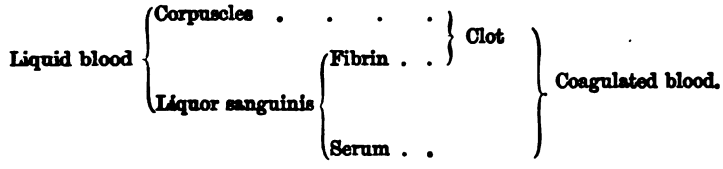
THE BLOOD.

The most striking external character of the blood is its well-known colour, which is bright red approaching to scarlet in the arteries, but of a dark purple or modena tint in the veins. It is a somewhat clammy and consistent liquid, a little heavier than water, its specific gravity being about 1·055; it has a saltish taste, a slight alkaline reaction, and a peculiar faint odour.

To the naked eye the blood appears opaque and homogeneous; but, when examined with the microscope, either while within the minute vessels, or when spread out into a thin layer upon a piece of glass, it is seen to consist of a transparent colourless fluid, named the "lymph of the blood," "liquor sanguinis," or "plasma," and minute solid particles or corpuscles immersed in it. These corpuscles are of two kinds, the coloured and the colourless: the former are by far the more abundant, and have been long known as "the red particles," or "globules," of the blood; the "colourless," "white," or "pale corpuscles," on the other hand, being fewer in number and less conspicuous, were later in being generally recognised.

When blood is drawn from the vessels, the liquor sanguinis separates into two parts;—into fibrin, which becomes solid, and a pale yellowish liquid named *serum*. The fibrin in solidifying involves the corpuscles and forms a red consistent mass, named the clot or *crassamentum* of the blood, from which the serum gradually separates. The relation between the above-mentioned constituents of the blood in the liquid and the coagulated states may be represented by the subjoined scheme:—



In a cubic millimeter of healthy human blood there are on an average 5,000,000 red corpuscles (Vierordt) and 10,000 white corpuscles. The number of white corpuscles varies much more than that of the red, and the proportion of the white to the red is variously given at from 1 : 1000 to 1:250. There are said to be fewer red corpuscles in the female (4,500,000 in a cubic millimeter according to Welcker).

The numeration of the blood-corpuscles is readily performed. A little blood, obtained by pricking the finger, is measured in a capillary tube, and is then mixed with a measured amount (say 100 times its volume) of dilute solution of sulphate of soda, or some other salt which will maintain its fluidity and at the same time preserve the corpuscles nearly unaltered; the latter can then be counted in a small known quantity of the mixture. This part of the operation is effected by placing a drop of the mixture in the middle of a glass "cell" of a certain depth (say $\frac{1}{10}$th of a millimeter), the bottom of which is ruled in squares, the sides of which are of a known dimension (say again $\frac{1}{10}$ mill.). If now a covering glass is placed over the cell so as to touch the drop, the latter will form a layer of the mixture $\frac{1}{10}$ mill. deep, and the part above each square will represent a cube of liquid the sides of which measure $\frac{1}{10}$ mill. So that by counting the number of corpuscles in a square, after allowing them time to subside, the number in this

volume of the mixture is obtained. It is clear that a simple calculation will then give the number in a cubic millimeter of the blood employed.

The methods of Hayem and Nachet, Gowers, and Thoma are based on the above principle. The average results obtained by recent investigators agree closely with the original estimates of Vierordt and Welcker.

RED CORPUSCLES OF THE BLOOD.

These are not spherical, as the name "globules," by which they were formerly designated, would seem to imply, but flattened or disk-shaped. Those of the human blood (fig. 21 and fig. 22, A) have a nearly circular outline, like a piece of coin, and most of them also present a shallow cup-like depression or dimple on both surfaces; their usual figure is, therefore, that of biconcave disks. Their magnitude differs somewhat even in the same drop of blood, and it has been variously assigned by authors; but the prevalent size may be stated at from $\frac{1}{3500}$th to $\frac{1}{3200}$th of an inch (·007 to ·008 millimeter)* in diameter, and about one-fourth of that in thickness.

Fig. 21.

Fig. 21.—HUMAN BLOOD AS SEEN ON THE WARM STAGE. MAGNIFIED ABOUT 1200 DIAMETERS (E. A. S.).

r, *r*, single red corpuscles seen lying flat; *r'*, *r'*, red corpuscles on their edge and viewed in profile; *r''*, red corpuscles arranged in rouleaux; *c*, *c*, crenate red corpuscles; *p*, a finely granular pale corpuscle; *g*, a coarsely granular pale corpuscle. Both have two or three distinct vacuoles, and were undergoing changes of shape at the moment of observation; in *g*, a nucleus also is visible.

In mammiferous animals generally, the red corpuscles are shaped as in man, except in the camel tribe, in which they have an elliptical outline. In birds, reptiles, amphibia, and most fishes, they are oval disks with a central elevation on both surfaces (fig. 22, B, and fig. 27, from the frog), the height and extent of which, as well as the proportionate length and breadth of the oval, vary in different instances, so that in some fishes the elliptical form is almost shortened into a circle.

The size of the corpuscles differs greatly in the different classes of Vertebrata; they are largest in the Amphibia. Thus in the frog they are about $\frac{1}{1000}$th of an inch long and $\frac{1}{1700}$th broad; in Proteus anguinus, $\frac{1}{400}$th of an inch long and $\frac{1}{727}$th broad: in Amphiuma tridactylum, where they are largest, the red corpuscles are one-third larger than those of the Proteus. In birds they range in length from about $\frac{1}{3}\frac{1}{00}$th to $\frac{1}{1700}$th of an inch. Amongst mammals the elephant has the largest red blood-corpuscles ($\frac{1}{2700}$th of an inch); those of the dog average $\frac{1}{3600}$th of an inch; those of the sheep $\frac{1}{5000}$th of an inch; the goat was long supposed

* The one-thousandth part of a millimeter is often known as a *micro-millimeter* or and is represented by the Greek letter μ. The diameter of a red blood corpuscle xpressed as 7—8 microns (7 μ—8 μ).

to have the smallest, ($\frac{1}{4420}$ th of an inch) but Gulliver found them about half this size in the Meminna and Napu deer.

In observations upon the blood of different races of mankind, Richardson found no constant difference, the average diameter of the red blood-corpuscle being $\frac{1}{3574}$ th of an inch. The corpuscles of many mammals, and notably the dog among the common domestic animals, approach so nearly in size to the human blood-corpuscles as to be quite undistinguishable from them.

Fig. 22.

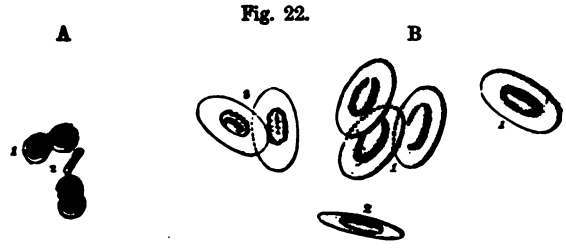


Fig. 22.—HUMAN RED CORPUSCLES (A) AND BLOOD CORPUSCLES OF THE FROG (B) PLACED SIDE BY SIDE TO SHOW RELATIVE SIZE. 500 DIAMETERS.

1, shows their broad surface; 2, one seen edgeways; 3, shows the effect of dilute acetic acid; the nucleus has become distinct (from Wagner).

When viewed singly by transmitted light the coloured corpuscles do not appear red, but merely of a reddish-yellow tinge, or yellowish-green in venous blood. It is only when the light traverses a number of corpuscles that a distinct red colour is produced.

In consequence of the shape of the corpuscle, it looks darker in the middle than at the edge when viewed with only a moderate magnifying power, or at a distant focus; but the middle of the corpuscle appears lighter than the periphery when a close focus or a very high magnifying power is employed.

The red disks, when blood is drawn from the vessels, sink in the plasma; they have a singular tendency to run together, and to cohere by their broad surfaces, so as to form by their aggregation cylindrical columns, like piles or rouleaus of money, and the rolls or piles themselves join together into an irregular network (figs. 21 and 23). Generally the corpuscles separate on a slight impulse, and they may then unite again. The phenomenon is most readily explained by supposing the substance composing the corpuscles to possess a slight natural adhesiveness (Lister). It will take place in blood which has been in any way brought to a standstill within the living vessels as well as in blood that has stood for some hours after it has been drawn, and also when the globules are immersed in serum in place of liquor sanguinis.

Fig. 23.

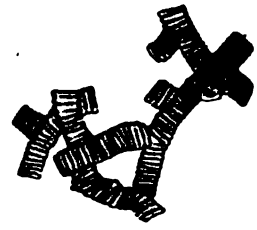


Fig. 23.—RED CORPUSCLES COLLECTED INTO ROLLS (after Henle).

The corpuscles alter their shape on the slightest pressure, as is well

seen while they move within the vessels; they are also elastic, for they readily recover their original form.

The human blood-corpuscles, as well as those of the lower animals, often present deviations from the natural shape, which are most probably due to causes acting after the blood has been drawn from the vessels, but in some instances depend upon abnormal conditions previously existing in the blood. Thus, it is not unusual for many of them to appear shrunken and crenated, when exposed under the microscope (fig. 21, *c*, *c*; fig. 24, *f*), and the number of corpuscles so altered often appears to increase during the time of observation. This is, perhaps, the most common change; it occurs whenever the density of the plasma is increased by the addition of a neutral salt, and is one of the first effects of the passage of an electric shock. The corpuscles may become distorted in various other ways, and corrugated on the surface; not unfrequently one of their concave sides is bent out, and they acquire a cup-like figure.

Gulliver made the curious discovery that the corpuscles of the Mexican deer and some allied species present very singular forms, doubtless in consequence of exposure; the figures they assume are various, but most of them become lengthened and pointed at the ends, and then often slightly bent, not unlike caraway-seeds.

Structure of the coloured blood corpuscles.—Each red corpuscle is formed of two distinct parts, a coloured and a colourless, but under ordinary circumstances the two are intimately commingled, so that every portion of the corpuscle, however small, has to all appearance the same constitution: the corpuscles therefore look homogeneous.

Of the two parts composing the corpuscle the one which imparts its colour to the blood-disk consists of a red crystallizable substance termed *hæmoglobin*, the colourless part is termed the *stroma*. Hæmoglobin is readily soluble in water, and the addition of this fluid to a drop of blood serves speedily to separate the coloured substance from the colourless part of the corpuscle (fig. 24, *a*—*e*). The same effect, namely,

Fig. 24.

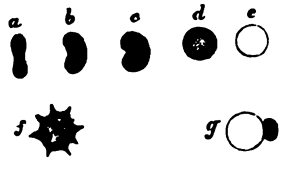


Fig. 24.—*a*–*e*, successive effects of water upon a red blood-corpuscle; *a*, corpuscle seen edgeways, slightly swollen; *b*, *c*, one of the sides bulged out (cup form); *d*, spherical form; *e*, decolorized stroma; *f*, a thorn-apple shaped corpuscle (due to exposure); *g*, action of tannin upon a red corpuscle.

the discharge of colouring matter from the corpuscles, may be produced by various other means, such as the action of heat (60° C.), the alternate freezing and thawing of a portion of blood, the action of ether and chloroform vapour, and the passage of electric shocks through blood; in these cases the hæmoglobin becomes dissolved by the serum. Many watery solutions, such as dilute acids, act like water itself. The effect of a solution of tannic acid is peculiar, from the fact that the hæmoglobin, although discharged from the corpuscle, yet being insoluble in the solution, is immediately precipitated upon the surface of the stroma in the form of a small darkly coloured globule (Fig. 24, *g*.) (W. Roberts).

The blood or serum of many animals belonging to different genera

cannot be mixed without producing the decolorization and destruction of the red corpuscles of one or both sorts of blood (Landois).

Blood in which the hæmoglobin has been dissolved out from the corpuscles by any of these means is seen to have lost its opaque appearance, and to have acquired a transparent laky tint; the change depends upon the fact that the colouring matter when dissolved in the serum and forming a homogeneous layer, interferes less with the transmission of light than when occurring in scattered particles.

Hæmoglobin after being thus separated from the blood-corpuscles is prone to undergo crystallization. The crystals present various forms in different animals, but almost all (the hexagonal plates of the squirrel being alone excepted) belong to the rhombic system. From human blood and that of most mammals, the crystals are elongated prisms (fig. 25, 1), but they are tetrahedrons in the guinea-pig (2), and short rhombohedrons in the hamster (4). They are most readily obtained for microscopical examination from the blood of the rat, where they appear merely on the addition of a little water.

Fig. 25.

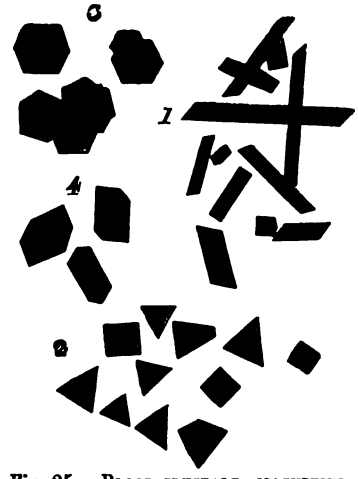


Fig. 25.—BLOOD-CRYSTALS, MAGNIFIED.
1, from human blood; 2, from the guinea-pig; 3, squirrel; 4, hamster.

All hæmoglobin crystals contain a certain amount of water of crystallization (Kühne). They are doubly refracting (anisotropous). The spectrum of hæmoglobin, whether in substance or in solution, may be always readily recognized by the double or single absorption bands, which are produced according as it is present in the oxidated or deoxidated condition (Stokes).

Other coloured crystals, which may be obtained from blood, are the so-called "hæmin crystals" of Teichmann. They are formed when hæmoglobin is warmed with a little salt and glacial acetic acid. On cooling, the hæmin crystallizes out in minute reddish-brown acicular prisms (fig. 26), the demonstration of which affords a positive proof of the presence of blood-colouring matter. They may readily be obtained from dried blood without the addition of salt, merely by warming it with concentrated acetic acid.

Fig. 26.

Fig. 26.—HÆMIN CRYSTALS, MAGNIFIED (from Preyer).

The amount of hæmoglobin in each corpuscle, which is liable to variation, may be approximately arrived at by determining both the number of corpuscles and the amount of hæmoglobin in a given volume of blood. The amount of hæmoglobin is estimated by diluting a sample of blood with a known amount of water, and comparing the tint of the solution so obtained with that of a solution of hæmoglobin of known strength. A very convenient means of quickly obtaining an idea of the amount of hæmoglobin in a sample of blood is afforded by the "hæmoglobinometer" of Gowers, which is arranged on the above principle.

The stroma of the red corpuscle during the removal of the hæmoglobin generally loses its discoid shape and becomes globular. It is itself composed of a number of chemical substances, chief among which are paraglobulin, cholesterin, and protagon.

STRUCTURE OF THE NUCLEATED RED CORPUSCLES OF THE LOWER VERTEBRATA.

Like the mammalian blood-discs the large corpuscles of the frog (fig. 27) and salamander, may be described as consisting of coloured substance and stroma. They differ from the mammalian corpuscles, however, in the possession of a more solid particle of an oval shape which lies imbedded in the stroma, and has been long known as the "nucleus." It is rather more than one-third the length of the corpuscle, but in the natural unaltered condition is seldom visible; this is probably owing to the fact that it possesses very nearly the same index of refraction as the rest of the corpuscle. For it may be rendered visible, even under such circumstances, by the combined action of watery vapour and carbonic acid upon the blood; a precipitate (of paraglobulin) is thus produced upon the nucleus, and its outline comes into view: on readmission of air the precipitate is re-dissolved, and the nucleus again becomes faint or disappears (Stricker).

The effect of most reagents is similar to that produced on human blood. Water causes both stroma and nucleus to swell up by imbibition, the coloured part being at the same time extracted. A dilute solution of acetic acid in an indifferent fluid also removes the colouring matter, but the stroma and nucleus retain their shape, the last-mentioned body presenting a markedly granular appearance (fig. 22, 3); if strong acetic acid be employed, the nucleus often acquires a reddish tint. Alkalies, on the other hand, even when very dilute, rapidly destroy both corpuscle and nucleus. Various reagents added to newt's blood cause the coloured part of the corpuscles to become gradually withdrawn from the stroma, and collected around the nucleus; this is especially the case with a two per cent. solution of boracic acid (Brücke): the coloured matter and nucleus ("zooid") may subsequently be altogether extruded from the body of the corpuscle ("oecoid").

Fig. 27.

Fig. 27.—Frog's blood (Ranvier).

a, red corpuscle seen on the flat; *v*, vacuole in a corpuscle; *b*, *c*, red corpuscles in profile; *n*, pale corpuscle at rest; *m*, pale corpuscle, exhibiting amœboid movements; *p*, coloured fusiform corpuscle.

Dilute alcohol brings to view one, or at most two, nucleoli within the nucleus of the amphibian red corpuscle (Ranvier, Stirling). In other respects also this structure resembles the nucleus of an ordinary cell, for it contains a network traversing its interior (fig. 28), which is, however, very close, and produces under moderate powers of the microscope a somewhat granular effect. It is doubtful whether the nucleus of the adult corpuscle can undergo division, although in the young state the division of the nucleus, followed or accompanied by that of the corpuscle, has frequently been observed.

A question which has been much discussed, is as to the existence of a membranous wall around the red corpuscle. The effects of the action of water and solution of salt respectively, seem in favour of the view that

such a membrane is present. The addition of water to the blood, causes the corpuscles, both those of man and of the frog, to lose their flattened shape and to become spherical; and since this change will occur long after the blood has been drawn, and cannot, for this and other reasons, be referred to the existence of contractility in the corpuscle, there is only one explanation which can be offered; namely, that water has passed into the corpuscle by osmosis, and has thus distended the corpuscle. In the same way the action of salt, in causing a crenation of the corpuscle, can be best explained by supposing that watery fluid has passed out from the corpuscle by osmosis, so that the superficial layer which envelopes the rest of the corpuscle is thrown into folds or creases. But it is not necessary to suppose that this enveloping layer is of the nature of a distinct membrane; for if we assume that the substance of the corpuscle has a more fluid consistence internally than near the exterior, a sufficient explanation of the phenomena resulting both from the action of water and of salt is obtained without asserting the existence of a definite membrane, a structure which no one has succeeded in demonstrating in an isolated form.

Fig. 28.

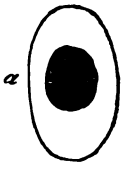


Fig. 28.—Coloured corpuscle of salamander, showing intra-nuclear network (Flemming).

Gaule has recently described the development under certain conditions within the red corpuscles of the frog of a minute organism which subsequently escapes from the corpuscle, and moves actively about in the surrounding fluid. Gaule is of opinion that the organism in question is formed out of the living substance (protoplasm, zooid) of the red corpuscle, and is an active free condition of this. It would seem, however, to be far more probably of a parasitic nature, developed from a minute invisible germ that had lain latent within the corpuscle, ready to undergo development under favourable conditions.

Under the influence of certain conditions (heat, presence of septic material) and reagents (urea solution, dilute sherry wine), the coloured blood-corpuscles often extrude fine beaded filaments which may attain a considerable length, and undergo varied changes. As Dowdeswell has correctly pointed out, these filamentous extrusions militate decidedly against the existence of a membranous envelope to the corpuscle. It is not by any means proven, however, that the filaments are protoplasmic in nature, like the amœboid processes of the colourless corpuscles, for it is possible to explain their occurrence by supposing that they are caused by the action of the fluid upon the protagon in the stroma, much in the same way as the well-known "myelin figures" are formed from the protagon in the white substance of nervous tissue when this is submitted to the action of water.

The affirmation of Böttcher that a nucleus is present in the mammalian red blood-corpuscle, rests entirely upon erroneous methods of preparation. That of Stricker (which is a revival of the older opinions of Wharton Jones, and of Busk and Huxley) that the mammalian red corpuscle is morphologically a nucleus with an imperceptible amount of enveloping cell-substance, is quite distinct from Böttcher's view, and has certain considerations to recommend it, but is supported, at present upon an insufficient basis of fact, and is opposed, moreover, to recent observations upon the development of the red disk.

COLOURLESS CORPUSCLES OF THE BLOOD.

General Characters.—The white, pale, or colourless corpuscles are few in number as compared with the red, and both on this account and because of their want of colour, they are not at first easily recognized in a microscopic preparation of blood. Their form is very various, but when absolutely at rest they are rounded or spheroidal. Measured in this condition they are found to be about $\frac{1}{100}$th of an inch (.001 mm.) in diameter. They are specifically lighter than the red corpuscles.

The white corpuscle may be taken as the type of a free animal cell. It is a minute protoplasmic structure inclosing one or more nuclei, and the protoplasm, being to all appearance unaltered from its primitive condition, and unenclosed in a definite membrane or cell-wall, is capable of exhibiting in a high degree the amœboid movements and other phenomena which depend upon the possession of contractility and have been already sufficiently described. The white blood-corpuscles are peculiarly apt to

Fig. 29.

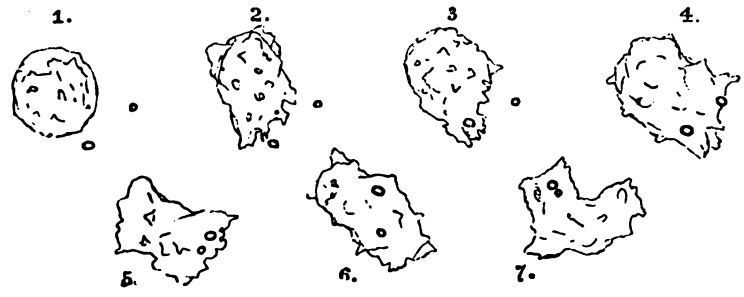


Fig. 29.—Changes of form of a white corpuscle of newt's blood, sketched at intervals of a few minutes. The figures show also the intussusception of two small starch granules, and the changes of position which these underwent within the corpuscle. (E. A. S.)

take into their interior minute solid particles that have been introduced into the blood (fig. 29); this property has served in the hands of Cohnheim and others as a means of detecting escaped white corpuscles in tissues which are wholly extravascular, such as the cornea. Some of the colourless corpuscles have in their protoplasm a number of comparatively coarse round granules (fig. 21, *g*) which are generally grouped together round the nucleus. These corpuscles are often distinguished from the more common paler variety, (fig. 21, *p*) as the coarsely granular cells, but it has not been shown that they are different in nature, origin, or destination.

Both coarsely granular and finely granular corpuscles are often seen, which are much smaller than the ordinary pale cells, consisting chiefly of a spheroidal nucleus with but little surrounding protoplasm. They seem to be young forms of the more protoplasmic corpuscles, and are perhaps identical with the lymphoid cells found in lymphatic glands and similar structures.

The corpuscles often have one or more conspicuous vacuoles in their protoplasm, but these are inconstant, and may appear and disappear in the same corpuscle. More rarely they are filled with vacuoles so that the cell-substance assumes a frothy aspect. This is commoner in the white blood-corpuscles of the newt and other cold-blooded animals than in those of man. By means of the amœboid movement of their protoplasm, the pale corpuscles, under some circumstances, possess the power of wandering or emigrating from the blood-vessels, penetrating between the elements of their coats, and in this manner they find their way into the interstices of the tissues, and hence into the commencements of the lymphatics. Cells like these which appear to be wandering independently in the tissues, and particularly in the connective tissue, are known as ***migratory cells.***

Besides the two forms of pale corpuscles previously referred to, others have been described which differ from them in containing red-coloured granules in their protoplasm. According to A. Schmidt and Semmer, such cells are very numerous in the circulating blood, but on withdrawal of the blood from the vessels they become rapidly destroyed and disappear without leaving a trace. Schmidt looks upon them as transitional forms between the white and red corpuscles, but the evidence of their constant occurrence in normal blood is at present unsatisfactory

The pale corpuscles possess one, two, or more nuclei, which are generally obscure in the living condition, but are occasionally seen when the cor-

Fig. 30.

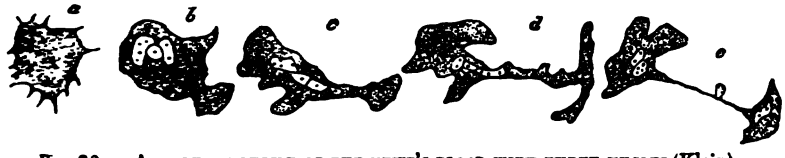


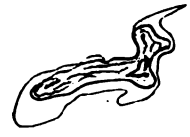
Fig. 30.—A PALE CORPUSCLE OF THE NEWT'S BLOOD WITH THREE NUCLEI (Klein).

a—*e*, successive forms assumed at intervals of a few minutes.

puscle becomes flattened out (fig. 30, *b*, *e*,) and may always be brought into view by reagents. The nuclei are apt to take on peculiar shapes, caused perhaps by traction exercised upon them by the movements of

Fig. 31.—A PALE CORPUSCLE OF THE SALAMANDER, SHOWING ELONGATED IRREGULAR NUCLEUS WITH INTRANUCLEAR NETWORK. (Flemming.)

Fig. 31.



the surrounding protoplasm. Thus a nucleus not unfrequently becomes elongated and either irregular in outline (fig. 31) or folded on itself, so that when the ends are turned up, the appearance of two nuclei is produced, where in reality there may be but one. In other respects they have the normal structure and appearance of cell-nuclei, containing the usual intranuclear network. The division of the nucleus and of the corpuscles takes place in the same way as in other animal cells, but it is probable that the phases are neither so numerous nor so complicated. The process, as observed in the newt's corpuscle, is as follows:—The nucleus becomes enlarged and transformed into a system of parallel fibres. The substance of the fibres gradually collects towards the two poles of the elongated nucleus, leaving the middle clear or bridged across only by fine filaments, while at each pole a new nucleus becomes formed. This is followed by a constriction of the protoplasm into two equal parts, which are collected around the two new nuclei. The change is accompanied by a radial arrangement of the granules in the protoplasm, the lines of granules converging towards the new nuclei.*

In some cases it would seem that the separation of the protoplasm may not occur until some time after the division of the nucleus has been completed; for white corpuscles are often seen containing two or more

* The changes of the nucleus have also been seen in the white corpuscles of the Salamander by Peremeschko.

nuclei, and such corpuscles have been observed to separate into two parts, each part taking with it a nucleus (Klein).

Action of Reagents.—Water swells up and destroys the protoplasm of the white corpuscles, setting free the granules. If but little water be mixed with the drop of blood, the protoplasm may not be destroyed, but the corpuscles are swollen out (fig. 32, 1), and the granules take on an active Brownian movement. Acetic acid causes a granular precipitate in the protoplasm, the granules collecting around the nucleus, which is brought very strongly into view (fig. 32, 2, 3). A

Fig. 32.

Fig. 32.—COLOURLESS CORPUSCLES TREATED WITH WATER AND WITH ACETIC ACID. (E.A.S.)

1, first effect of the action of water upon a white blood-corpuscle; 2, 3, white corpuscles treated with dilute acetic acid; *n.* nucleus.

clear bleb-like swelling is also generally produced from one or more sides of the corpuscle: but this appearance is not peculiar to acids, for it is often seen as an accompaniment of the death of the corpuscle, whether as the result of the action of reagents or from any cause. If produced by a solution of iodine, the blebs sometimes become coloured of a faint port wine tint, a reaction which is generally taken as an indication of the presence of glycogen.

In the blood of the splenic vein, and also in some other parts, cells have been noticed resembling pale corpuscles in their structure, but much larger, and enclosing in their protoplasm a number of red corpuscles, or in some cases partially disintegrated portions of red corpuscles. These are supposed to be pale cells which have taken in some of the red corpuscles, a process which appears to occur normally in the spleen itself.

Other microscopic elements in blood.—In the clear fluid which intervenes between the corpuscles, and which, in a preparation which has been made a short time, consists of serum, there can generally be detected a network of fine interlacing filaments of fibrin. There are also to be seen minute round colourless particles in this fluid, which become more evident after the preparation has been made for some time, or if the blood has been diluted with certain fluids. They are known as the *elementary particles* of Zimmermann, and especial attention has been lately drawn to them by Hayem, who re-describes them under the name "hæmatoblasts" as the source whence new red corpuscles are derived (see Development of Blood Corpuscles). Besides these scattered elementary particles, granular-looking masses (fig. 33), composed of exceedingly fine colourless particles, frequently occur in a drop of blood drawn from the finger, even when it is taken from a healthy person, but especially in cachectic states of the system. The particles are free in the circulating blood, but become massed together immediately that the blood is drawn (Osler). If one of the masses be observed for a time, at the temperature of the body, it may sometimes be seen that the minute particles composing it have grown out into or at least have become connected with delicate filaments which presently take on an oscillatory Brownian movement, by

virtue of which they eventually break away from the mass and become free in the surrounding liquid. According to Ranvier the filaments in question are fibrin-filaments.

Fig. 33.

Fig. 33.—GRANULAR MASS OF MAX SCHULTZE, OBSERVED IN SALT SOLUTION ON THE WARM STAGE, SHOWING THE CHANGES WHICH IT UNDERGOES AT ITS PERIPHERY. (Osler).

If blood be taken from an animal during digestion, especially of a meal containing much fatty food, the serum or plasma has a milky aspect. This is due to the presence of innumerable fine fatty molecules which have been absorbed from the intestines and discharged with the chyle into the blood.

THE LYMPH AND CHYLE.

A transparent and nearly colourless fluid, named "lymph," is conveyed into the blood by a set of vessels distinct from those of the sanguiferous system. These vessels, which are named "lymphatics," from the nature of their contents, and "absorbents," on account of their reputed office, take their rise in nearly all parts of the body, and, after a longer or shorter course, discharge themselves into the great veins of the neck; the greater number of them previously joining into a main trunk, named the thoracic duct,—a long narrow vessel which passes in front of the vertebræ, and opens into the veins on the left side of the neck, at the angle of union of the subclavian and internal jugular; whilst the remaining lymphatics terminate in the corresponding veins of the right side. The absorbents of the small intestine carry an opaque white liquid, named "chyle," which they absorb from the food as it passes along the alimentary canal; and, on account of the milky aspect of their contents, they have been called the "lacteal vessels." But in thus distinguishing these vessels by name, it must be remembered that they differ from the rest of the absorbents only in the nature of the matter which they convey; and that this difference holds good only while digestion is going on; for at other times the lacteals contain a clear fluid, not to be distinguished from lymph. The lacteals enter the commencement of the thoracic duct, and the chyle mingling with the lymph derived from the lower part of the body, is conveyed along that canal into the blood. Both lacteals and lymphatics, in proceeding to their destination, pass into and out of certain small, solid and vascular bodies, named lymphatic glands, which have a special structure and internal arrangement, as will be afterwards described; so that both the chyle and lymph are sent through these glands before being mixed with the blood.

Thus much having been explained to render intelligible what follows, we may now consider the lymph and the chyle, which, as will be seen, are intimately related to the blood.

Lymph, when examined with the microscope, is seen to consist of a clear liquid with corpuscles floating in it. The liquid part—lymph-plasma—bears a strong resemblance in its physical and chemical constitution to the plasma of the blood. The lymph-corpuscles agree entirely in their characters with the pale corpuscles of the blood. They vary in number in lymph from different parts, being more numerous in that which has passed through the lymphatic glands than in the lymph which enters those

[illegible] lymphatic glands as an important source of [illegible] the corpuscles found in lymph are of small [illegible] amount of protoplasm and a relatively large [illegible] the lymphoid cells of lymphatic glands. [illegible] amœboid than those which are larger and [illegible] Since the lymph is poured into the blood, the [illegible] looked upon as constantly furnishing a fresh [illegible] that fluid.

[illegible] have seen merely of lymph, to which are added [illegible] products of digestion. These are chiefly particles [illegible] oil-globules, some of which are of appreciable [illegible] number are immeasurably small. Like the fatty [illegible] milk, they give the chyle a similar milky aspect. [illegible] particles were named collectively by Gulliver the [illegible] the chyle.

[illegible] ordinary lymph-corpuscles but with a reddish tinge, [illegible] in the lymph and chyle as well as in the blood, and [illegible] been noticed, but these may have got into the lymph through a rupture of the fine vessels.

[illegible] white blood-corpuscles and of the corpuscles of the lymph [illegible] the origin of the lymph and chyle corpuscles, it may, in the [illegible] observed that the greatly increased proportion of these bodies in the [illegible] issue from the lymphatic glands, and the vast store of corpuscles [illegible] characters contained in the interior recesses of these glands, [illegible] indications that the glands are at least a principal seat of [illegible]. They are, most probably, produced by division of parent cor- [illegible] contained in the glands, and in some measure also by further [illegible] corpuscles thus produced after they have made their way into the [illegible] vessels. The corpuscles found sparingly both in chyle and lymph [illegible] passing the mesenteric glands may be in part formed in the lymphatic [illegible] met with in the alimentary mucous membrane and other parts of the [illegible]. Pale corpuscles also, which have migrated from the vessels, may find [illegible] way into the beginning of the lymphatics. In this way the presence of [illegible] in the lymph even before it has passed through the lymphatic glands [illegible] accounted for. Lymph-corpuscles are probably also produced in the spleen and in the thymus gland; and it is believed by some that they may also be formed by proliferation of connective tissue corpuscles. The corpuscles of the chyle and lymph are carried into the sanguiferous system and become the pale corpuscles of the blood, but some of the latter may pass directly from the lymphatic glands, spleen, and other organs containing lymphatic or lymphoid tissue into the blood-vessels which are supplied to those organs.

DEVELOPMENT OF THE RED BLOOD-CORPUSCLES.

Origin of the nucleated red blood-corpuscles of the embryo.—The first red blood-corpuscles are formed very early in embryonic life simultaneously with and in the interior of the first blood-vessels. They are developed in the mesoderm, in a circular area which surrounds the part of the blastoderm which is occupied by the developing body of the embryo. The area is known as the vascular area, and the first blood-vessels and blood-corpuscles are, therefore, formed outside the actual body of the embryo. The process of development is as follows:—

Those mesodermic cells in the vascular area which are concerned with the formation of vessels become extended into processes of varying length, which grow out from the cells in two or more directions. The cells become united with one another, either directly or by the junction of their processes, so that an irregular network of protoplasmic nucleated corpuscles is thus formed (fig. 34). Meanwhile

the nuclei become multiplied, and whilst the greater number remain grouped together in the original cell-bodies or nodes of the network, some are seen in the uniting cords. The nuclei which remain in the centre of the nodes accumulate, each one around itself, a small amount of the cell protoplasm. The corpuscles thus formed (*bl*) acquire a reddish colour, and the protoplasmic network in which they lie becomes vacuolated and hollowed out into a system of branched canals enclosing fluid, in which the nucleated coloured corpuscles float. The intercommunicating canals gradually become enlarged so as to admit of the passage of the

Fig. 34.

Fig. 34.—PART OF THE NETWORK OF DEVELOPING BLOOD-VESSELS IN THE VASCULAR AREA OF THE GUINEA-PIG. (E. A. S.)

bl, blood-corpuscles becoming free in an enlarged and hollowed out part of the network. The smaller figure on the left represents *a* of the larger figure, more highly magnified ; *d*, a nucleus undergoing division.

corpuscles. The protoplasm which forms the wall of these first vessels becomes differentiated around the nuclei which have remained embedded in it, so as to give rise to the flat cells which compose the blood-capillaries.

As soon as the heart is developed, or even before this happens, the blood begins to move within the vessels of the vascular area. And when the action of the heart commences, it is driven also through vessels which are formed, probably in a similar manner, in the body of the embryo itself.

The first formed red blood-corpuscles are nucleated cells resembling the pale corpuscles except in their colour and in the clearness of their protoplasm, and, like the white corpuscles, they are capable of amœboid movement, and of undergoing multiplication by division. It is uncertain whether, as stated by Kölliker and others, any of the primary red blood-corpuscles are produced by direct transformation of individual cells of the mesoderm, but (whether by accession of some of these last, by division, or by a continuance of the original mode of formation), they increase considerably in number, and are soon accompanied by colourless corpuscles. These appear to be formed in great number in the embryonic liver as soon as this is developed, as well as in the lymphatic glands, spleen and thymus gland. It is generally supposed that the colourless corpuscles acquire colour, and are converted into nucleated red corpuscles, but there is no direct evidence in favour of this view.

The primary nucleated red corpuscles are at length succeeded by smaller disk-shaped red corpuscles without nuclei, having all the characters of the blood-disks of the adult. This substitution proceeds gradually, until, long before the end of intrauterine life, the *nucleated* red corpuscles have almost entirely vanished. According to Neumann, some are still to be met with even in the new-born child. It is uncertain whether the nucleated red corpuscles are converted into non-nucleated disks, or if they simply disappear as the red disks become formed.

Origin of the Red Blood-Disks.—1. Intracellular origin. The disk-shaped red corpuscles are produced in the interior of mesodermic or connective tissue cells in the following manner:—

A part of the protoplasm of the cell acquires a reddish tinge (fig. 35, *h*), and after a time the coloured substance becomes condensed in the form of globules (*h'*) within the cells, varying in size from a minute speck to a spheroid of the

Fig. 35.

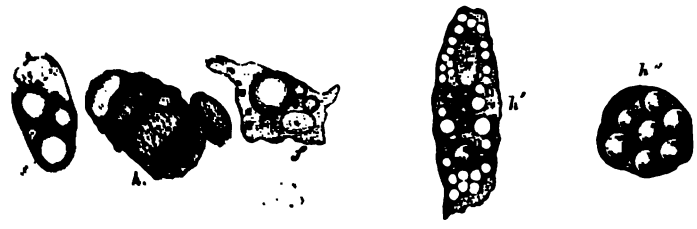


Fig. 35. DEVELOPMENT OF RED CORPUSCLES IN CONNECTIVE TISSUE CELLS. FROM THE SUBCUTANEOUS TISSUE OF THE NEW-BORN RAT. (E. A. S.)

h, a cell containing hæmoglobin in a diffused form in the protoplasm; *h'*, one containing coloured globules of varying size, and vacuoles; *h''*, a cell filled with coloured globules of nearly uniform size; *f*, *f'*, developing fat cells.

diameter of a blood-corpuscle, or even larger; but gradually the size becomes more uniform (fig. 35, *h''*). Some parts of the embryonic connective tissue, especially where a vascular tissue, such as the fat, is about to be developed, are completely studded with cells like these, occupied by a number of coloured spheroids and forming nests of blood-corpuscles, or minute "blood-islands." After a time the cells become elongated and pointed at their ends, and processes grow out to join prolongations of neighbouring blood-vessels or of similar cells. At the same time vacuoles form within them (fig. 35, *h'*), and becoming enlarged coalesce to form a cavity filled with fluid, in which the reddish globules, which are now becoming disk-shaped, float (fig. 36). Finally the cavity extends through the cell processes into those of neighbouring cells, and a vascular net-work is produced, and this becomes eventually united with pre-existing blood-vessels, so that the blood-corpuscles which have been formed within the cells in the manner described, get into the general circulation (see Development of Blood-vessels).

Fig. 36.

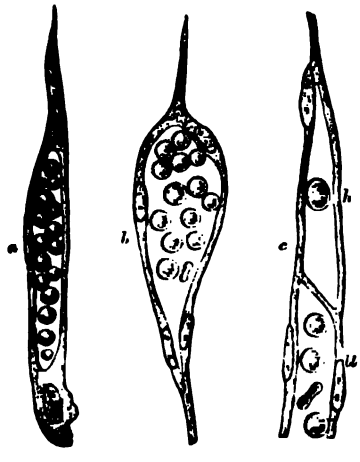


Fig. 36.—FURTHER DEVELOPMENT OF BLOOD-CORPUSCLES IN CONNECTIVE TISSUE CELLS, AND TRANSFORMATION OF THE LATTER INTO CAPILLARY BLOOD-VESSELS. (E. A. S.)

a, an elongated cell with a cavity in its protoplasm occupied by fluid and by blood-corpuscles which are still globular; *b*, a hollow cell the nucleus of which has multiplied. The new nuclei are arranged around the wall of the cavity, the corpuscles in which have now become discoid; *c*, shows the mode of union of a "hæmapoietic" cell, which in this instance contains only one corpuscle, with the prolongation (*bl*) of a previously existing vessel. *a*, and *c*, from the new-born rat; *b*, from a fœtal sheep.

This "intracellular" mode of development of red blood-corpuscles ceases in most animals before birth, although in those which, like the rat, are born very

immature, it may be continued for a few days after birth. Subsequently, although new vessels are formed in the same way, blood-corpuscles are not produced within them, and it becomes necessary to seek for some other source of origin of the red blood-disks, both during the remainder of the period of growth, and also during adult life, for it is certain that the blood-corpuscles are not exempted from the continual expenditure and fresh supply which affect all the other tissues of the body.

2. Origin from white corpuscles.—The view which long obtained most prevalence, and was supported by the opinions of Hewson, Wharton Jones, Kölliker, Paget, Busk and Huxley, and others, is that the red disks are developed from the white corpuscles, and the statements of A. Schmidt and of Semmer above mentioned (see p. 31), would seem to confirm this view. For if corpuscles are present in the blood which present transitional forms between the white and red corpuscles, it is probable that these are white corpuscles in process of transformation into red. There are, however, no other recorded observations of recent date which show conclusively that the red corpuscles are thus developed.

3. In the marrow of bones.—In the peculiar pale cells of the red marrow which fills the internal cavities of many bones, and particularly the ribs, appearances have been observed which justify the inference that red blood-corpuscles are here becoming developed. These appearances, in the shape of transitional forms between the marrow-cells and red corpuscles, were long ago described by Neumann, and by Bizzozero, and have been noticed also by other observers. The accounts are, however, somewhat different; for, according to Bizzozero, the *nucleus* of the marrow-cell becomes coloured, and with a small amount of protoplasm persists as the red disk, while Neumann described the *protoplasm* as becoming transformed into the red corpuscle whilst the nucleus disappears.

Observations which I have myself made on the red marrow of the guinea-pig have tended to confirm the view taken by Neumann, in that they have made evident that the colour of these so-called "transition-cells" is not situated in the nucleus, but chiefly if not entirely resides in the protoplasm; moreover the coloured cells that I have noticed have almost always been distinctly smaller than the ordinary marrow-cells, often of irregular forms, and sometimes appear as if undergoing division (fig. 37). They closely resemble, in fact, the nucleated red blood-corpuscles of the embryo, which may certainly thus multiply (by division), and it is not altogether improbable that the cells in question are descendants of the embryonic red blood-corpuscles, and not necessarily transition-forms between marrow-cells and the red blood-disks. By this opinion it is not intended to imply that blood-disks are not eventually produced from the coloured cells here spoken of.

Fig. 37.

Fig. 37.—Coloured nucleated cells from the red marrow of the guinea-pig. (E. A. S.)

Rindfleisch has recently given a detailed account of the manner in which such a production of red blood-disks is effected in the marrow, as follows:—

The marrow-cells, which are very like large pale blood-corpuscles, but with a less granular protoplasm and a larger more distinct nucleus, acquire a reddish tinge in consequence of the formation of hæmoglobin in the protoplasm. The colour becomes gradually more pronounced, and soon it is found that it is confined to a part only of the protoplasm. Presently the coloured protoplasm gradually becomes separated from the rest of the cell, and forms a red corpuscle which is at first cup-shaped, but afterwards becomes moulded in the circulation to form a biconcave disk. The protoplasm which is left in connection with the nucleus may, it is supposed, grow again and serve to form another red corpuscle, and so on, the newly formed corpuscles passing meanwhile into the circulation.

It must be added that Rindfleisch has not actually observed the separation of the two parts of the corpuscle; and that the opinion he expresses that the bicon-

cave form is the result of mechanical impressions upon the cup-shaped corpuscles during their passage through the vessels will not hold good for those red disks which are developed as such in the interior of cells in the manner described in paragraph 1, and is therefore rendered unnecessary in regard to other cases.

4. In the spleen.—It has long been believed that the formation of red blood-corpuscles is carried on in the spleen pulp, but this view has been in many quarters supplanted by the contrary one that a destruction of red corpuscles rather than a new formation may there take place, in support of which many facts were brought forward by Kölliker. The former view has, however, been again brought into prominence by Bizzozero, who describes in the spleen pulp after severe loss of blood, nucleated red corpuscles like those in the marrow, and further finds that there are more red as well as white corpuscles in the blood of the splenic vein than in that of the corresponding artery. The subject is one which needs reinvestigation.

5. From the corpuscles of Zimmermann. — Hayem describes as the precursors of the red blood-corpuscles in mammals the small colourless disks which are found floating freely in the blood, and are known as the elementary particles of Zimmermann. To these he applies the name "hæmatoblasts," and he maintains that they acquire colour, and by a gradual increase in size become directly transformed into red corpuscles. In support of this view he asserts that red corpuscles which are much smaller than the ordinary ones are to be almost always met with in blood, and that these smaller forms are especially numerous in cases where there has been previously a considerable loss of blood, and in which, therefore, it may well be supposed that a new formation of red corpuscles is proceeding; and further that they present every transition between the corpuscles of Zimmermann and the red disks.* In the frog Hayem describes as hæmatoblasts, spindle-shaped cells something like the white corpuscles, but of more delicate appearance (like the corpuscle marked *p* in fig. 27). These become, according to him, converted directly into red corpuscles, after undergoing an increase of size and a change of shape, in addition to the accession of colouring matter. They had been long previously noticed by Recklinghausen, and regarded as transition forms between the white and red corpuscles.

Historical.—The development of blood-corpuscles in isolated patches in the vascular area of the chick was first recognised by Pander, who termed the patches "blood-islands." Remak, and after him, His and Kölliker described the first vessels in the vascular area of the chick as originating in the form of a solid cord of mesodermic cells, arranged so as to form a network; the peripheral cells of the vascular cords becoming flattened and forming the epithelium of the vessels, whilst the centrally placed cells become directly converted into blood-corpuscles, acquiring colour first of all at certain points—the blood-islands of Pander—and fluid accumulating between them to form the liquor sanguinis. His stated, moreover, that the blood-vessels within the body of the embryo originate as ingrowths from these vessels of the vascular area. Stricker was the first to describe the formation of blood-vessels by the hollowing out of connective tissue cells, and Afanasieff and Klein proved that the blood-islands of Pander were cells of the mesoderm, in the interior of which blood-corpuscles had made their appearance, and that the containing cells became the first blood-vessels. Klein's account was confirmed, and in some particulars modified by Balfour. The account above given of the formation of vessels and blood-corpuscles in the vascular area of mammals is derived from original observations upon the embryo of the guinea-pig, which have not previously been published *in extenso*. The production of red blood-disks in the interior of cells of the connective tissue was first noticed by me in the subcutaneous connective tissue of the new-born rat, and subsequently in the embryos of a number of different animals, and these observations have been confirmed by Ranvier—who terms the connective tissue cells concerned in the process "vasoformative cells"—as well as by Lebouc and others. It is probable

* A similar account of the development of the red disks was given by Zimmermann; but many of the transitional forms which he described were red corpuscles which had been decolourised by the action of water.

that various appearances which have been described and differently interpreted —*e.g.*, the protoplasmic masses filled with blood-corpuscles noticed by Neumann in the embryonic liver—relate to the same phenomenon.

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EPITHELIAL TISSUE.

General nature and situation.—It is well known, that when the skin is blistered, a thin, and nearly transparent membrane, named the cuticle or epidermis, is raised from its surface. In like manner a transparent film may be raised from the lining membrane of the mouth, similar in nature to the epidermis, although it has in this situation received the name of "epithelium;" and under the latter appellation, a coating of the same kind exists on nearly all free surfaces and membranes of the body.

The following are the most important situations in which a covering or lining of epithelial tissue is found: viz., 1. On the surface of the skin. 2. On mucous membranes; a class of membranes to be afterwards

l, which line those internal cavities and passages of the body n exteriorly,—viz., the alimentary canal, the lachrymal, nasal, c, respiratory, urinary, and genital passages; as well as the glandular recesses and ducts of glands, which open into these or upon the surface of the skin. 3. On the inner or free surface s membranes, which line the walls of closed cavities in the chest, l, and other parts. 4. On the inner surface of the heart, blood- nd lymphatics.

y parts of the connective tissue the cells of that tissue are flattened out nged close together, edge to edge, in such a manner as to form a e of cells, which so far would come under the definition of the term m. But the cells in question exhibit every transition to the other the connective tissue, so that the enumeration of them under epi- would create an artificial separation between cells of the same elemen- re. They may, however, be conveniently described as epithelium- dthelioid. Many histologists are of opinion that a similar distinction s made for the epithelium of the serous membranes and of the vessels, hese are developed in the mesoderm and in connective tissue, and it lowing up of this idea which has led to the wide-spread adoption of the lcally incorrect word "endothelium" to express an epithelium so derived.* very epithelium which originates in the mesoderm is to be separated, be compelled to separate from the other epithelial tissues, with which in every way closely allied, the epithelia of the renal, and of the e organs, since these are derived from a part of the same layer of ives origin to the epithelium of the serous membranes. And indeed, as been shown in more than one instance amongst invertebrates, and rtebrate (Amphioxus), that the epithelium of the serous cavities, and t of the vascular system, is directly derived from an undoubtedly layer—namely, the entoderm—it is not improbable that this may be the nd typical mode of origin of the so-called endothelia, although it may me obscured in the more complicated course of development of higher a. And if this is the case, there is still less reason to regard "endo- " as a distinct variety of tissue, and to separate it from the epithelial ith which it has so long been classed.

ture of Epithelial Tissue in general.—Every epithelial formed entirely of cells united together by cohesive matter, often in too small quantity to be apparent. The layer or layers med take the shape of the surface to which they are applied, g accurately all its eminences and depressions. No blood-vessels e into epithelial tissue, although in some cases minute channels st between the cells into which the plasma of the blood derived e blood-vessels of the subjacent connective tissue may pass for ition of the epithelium cells.

s are abundant in many epithelia, the nervous fibrils passing in a of fine varicose filaments among the epithelium cells.

term "epithelia," which has passed into "epithelium," was introduced by o designate the cuticular covering on the red part of the lips. The word is" he considered inappropriate, as the subjacent surface is not skin (*derma*); is beset with papillæ, he named the covering layer "epi-thelia," from ἐπί and ipple or papilla. The use of the term has, by a not unusual license, been so as to signify the same kind of coating when it spreads over non-papillary

The word "endothelium," recently applied by some German writers to h what has heretofore been spoken of as the epithelium lining the serous s, and the inner surface of blood-vessels and lymphatics, appears to me a nnovation, and, considering the literal meaning of the word, not a happy one.— r. Sharpey.

In certain situations branched connective tissue cells which may contain pigment lie in the intercellular substance, whilst "migratory cells" are of frequent occurrence between the cells of an epithelium.

Epithelium cells vary in structure as well as in shape, and some of these differences will be mentioned in speaking of the varieties of epithelium. The nucleus varies, however, far less than the rest of the cell: in most cases it has an intranuclear network and one or more nucleoli. In the division of epithelium cells, it undergoes the changes which have already been described.

According to Klein's observations the protoplasm of all kinds of epithelium-cells is a fine reticulum, and this reticulum is in continuity with the intra-nuclear network. This is illustrated in the four cells shown in the accompanying figure (fig. 38).

Fig. 38

Fig. 38.—Structure of different epithelium cells according to Klein.

1, an ordinary epithelium cell; 2, a ciliated cell; 3, a columnar cell; 4, a mucous "goblet" cell.

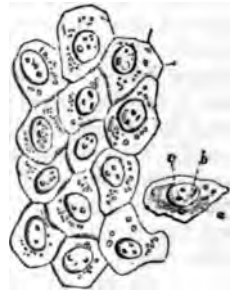
Classification of Epithelia.—The varieties of epithelium may be classified in various ways, but none perhaps are altogether satisfactory. Thus we may distinguish an epithelium according to its origin, as ectodermic, mesodermic, or entodermic, and this distinction is partially indicated when a separate term (endothelium) is used to denote mesodermic epithelium. Or again, the epithelia may be classed according to their function, and in this way we distinguish between the protective, the secreting, the ciliated, and the sense epithelia. But without failing to recognize that these modes of classification have a certain amount of importance, it will be most convenient here to follow the prevalent custom, and to classify the varieties of epithelium cells according to their shape and arrangement.

In the first place we may distinguish an epithelium which is composed of only a single layer of cells as a *simple* epithelium in contra-distinction to a *stratified* epithelium, in which the layers of cells are numerous. Where, on the other hand, the cells are in more than a single layer, but the two or three layers dove-tail the one into the other, so that the structure is not distinctly stratified, the term *transitional* may be employed; since this kind of arrangement is often found in places

re a simple epithelium passes gradually into one of the stratified ety.

imple Epithelia.—1. Pavement. Amongst simple epithelia the most common variety e *tesselated* or *pavement*, or as it is some- s named, the simple scaly epithelium. In the cells form polygonal plates or scales,

Fig. 39.



39.—PAVEMENT EPITHELIUM FROM A SEROUS MEMBRANE (PERITONEUM); MAGNIFIED 410 DIAMETERS.

a, cell-body; *b*, nucleus; *c*, nucleoli (Henle).

h fit together by their edges like the tiles mosaic pavement. The lines of junction e cells may be straight, or they may be more s jagged or sinuous. The mesodermic lia, such as the epithelium of serous membranes and of the , belong, for the most part, to this variety, but it includes also thelium lining the alveoli of the lungs which is of entodermic that covering the outer surface of the membrana tympani, and ing the mammary ducts, both of which are ectodermic.

olumnar. A second variety of simple epithelium is the *columnar*, *der* epithelium, in which the cells have a prismatic figure, and are right on the surface which they cover. In profile a row of these looks for the most part like a close palisade (fig. 41); but viewed

Fig. 40.

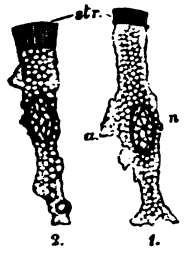


Fig. 41.

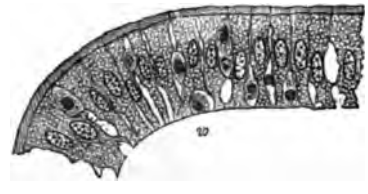


Fig. 40.—COLUMNAR EPITHELIUM CELLS OF THE RABBIT'S INTESTINE (E. A. S.).

e cells have been isolated after maceration in very weak chromic acid. They nuch vacuolated, and one of them (2) has a fat-globule near its attached end; the ed border (*str.*) is well seen, and the bright disk separating this from the cell-proto- ; *n*, nucleus with intranuclear network; *a*, a thinned out wing-like projection of ell which probably fitted between two adjacent cells.

Fig. 41.—A ROW OF COLUMNAR CELLS FROM AN INTESTINAL VILLUS OF THE RABBIT (E. A. S.).

, striated border; *w*, smaller cells between the epithelium cells, probably of the e of pale blood- or lymph-corpuscles.

the surface each cell has a polygonal outline, the cells being ened where they touch, from mutual compression, so that thus n a mosaic pattern is produced. Columnar epithelium cells vary h in form, in dimensions, and even in structure. Those which may ooked upon as typical are of a long tapering figure, the finer ex- ity being set upon a surface, and the other and larger end being . At their sides and edges the columnar cells are often irregular

In certain situations branched connective tissue cells contain pigment lie in the intercellular substance, whilst cells" are of frequent occurrence between the cells of an epi

Epithelium cells vary in structure as well as in shape these differences will be mentioned in speaking of the v thelium. The nucleus varies, however, far less than the in most cases it has an intranuclear network and one In the division of epithelium cells, it undergoes the ch already been described.

According to Klein's observations the protoplas epithelium-cells is a fine reticulum, and this reticulu with the intra-nuclear network. This is illustrat shown in the accompanying figure (fig. 38).

Fig. 38

Fig. 38.—Structure of different ep

1, an ordinary epithelium cell; 2, a cil "goblet" cell.

Classification of Epithelia classified in various ways, but n Thus we may distinguish an ectodermic, mesodermic, or en indicated when a separate la dermic epithelium. Or again their function, and in this the secreting, the ciliated, to recognize that these mo importance, it will be n custom, and to classify their shape and arrangem

In the first place we of only a single layer to a *stratified* epith Where, on the other the two or three structure is not employed; since

ve another peculiarity. The ll in being much more highly ated border of the cell (figs. 4 cuticular layer, and it is thereby thing different from the cell-proto r to offer a greater resistance to the destroy the protoplasm of the cel After having been hardened by re the rest of the cell, and since the cells often adhere together, a con obtained, marked by fine lines indi the cells from which this "cuticula" the striæ may either represent minut appeared by Kölliker and Funke, or they of solid rods or columns composing and Steinach, as well as by Henle. It that the striated cuticula is not imme protoplasm of the cell, but is separated from substance which refracts the light ever This disk (shown in fig. 40) correspond

a situation to the bright border of the ciliated epithelium cells (see below), and it is possible that the striated border is the morphological equivalent of the bunch of cilia upon those cells. Columnar epithelium cells are met with in their most characteristic form lining the mucous membrane of the intestines.

Some columnar epithelium cells are very long, others very short, so as to look cubical when seen in profile. They vary in form, moreover, according to the shape of the surface which they cover, thus they may be larger at the base than at the free end, as when they line a tube or duct, and in a section of this they then appear wedge-shaped.

Fig. 43.

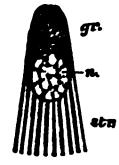


Fig. 43.—Striated epithelium cell, from the duct of a salivary gland (E. A. S.). highly magnified.

gr, granular protoplasm; *str*, striated protoplasm; *n*, nucleus.

Some epithelium cells, which must be reckoned in with this variety, have a peculiar striated aspect in the basal or fixed half of the cell (fig. 43, *str.*). This is the case with the cells which line the smaller ducts of the salivary glands and some of the tubules of the kidney.

In the human subject, columnar epithelium is chiefly but by no means exclusively derived from the entoderm.

3. Spheroidal or glandular Epithelium.—The cells composing a simple epithelium, are in some cases solid and rounded or polyhedral in shape, no one dimension especially predominating. This variety of epithelium is named *spheroidal*, or since it is chiefly characteristic of the terminal recesses or alveoli of secreting glands,

Fig. 44.

Fig. 44.—Transverse section of two glands of the stomach showing the ovoidal and polyhedral secreting cells (Heidenhain).

it is often known as *glandular*. The protoplasm of the cells is generally occupied by the materials which the gland secretes.

Fig. 45.

Fig. 45.—Three polyhedral epithelium cells from the liver of the guinea-pig (Klein).

The protoplasm of the cells has a reticular aspect.

4. Ciliated Epithelium.—Lastly the cells of a simple epithelium may bear on their basal or free ends spontaneously moving filaments named *cilia*. In the human subject the ciliated epithelium is not always perfectly simple, for there

Fig. 46.

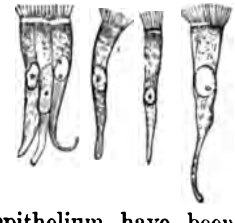


Fig. 46.—Columnar ciliated epithelium cells from the human nasal membrane; magnified 300 diameters (Sharpey).

are often other non-ciliated cells placed between the attached ends of those which bear the cilia. The ciliated epithelium will be best considered as a whole after the remaining varieties of epithelium have been touched upon.

Stratified Epithelium.—In a stratified epithelium the cells, as we have seen, are disposed in a number of layers, and it is commonly found that the cells of these various layers exhibit every variety of shape. As

Fig. 47.

Fig. 47.—Section of the stratified epithelium covering the front of the cornea of the eye. Highly magnified. (E. A. S.)

c, lowermost columnar cells; *p*, polygonal cells above these; *fl*, flattened cells near the surface. The intercellular channels, bridged by minute processes of the cell, are well seen. The lower part of the section on the right is somewhat broken.

a rule the cells of the deepest or attached layer are columnar (fig. 47, *c*), and the superficial cells are flattened scales (fig. 47, *fl*) which may be of considerable size, but which do not, like the cells of pavement or simple scaly epithelium, fit together by their edges, but, on the contrary, overlap one another (fig. 48). The cells of the

Fig. 48.

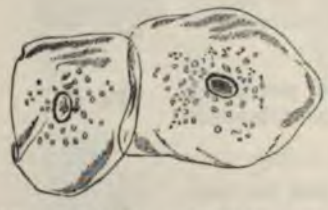


Fig. 48.—Epithelium-scales from the inside of the mouth; magnified 260 diameters (Henle).

layers immediately external to the columnar layer are rounded in shape, or at least only so far modified as to enable them to fit to the columnar cells and to one another (fig. 47, *p*); but as we trace the strata towards the surface, we find the component cells becoming more flattened and larger, whilst at the same time undergoing a change in their chemical constitution, so that at first the external part, and afterwards the whole of the protoplasm of the cell, is converted into horny substance, even the nucleus being at last involved.

The deeper protoplasmic cells of a stratified epithelium are continually multiplying by cell-division, and, as the new cells which are thus produced in the deeper parts increase in size, they compress and push outwards those previously formed. In this way cells which were at first deeply seated, become gradually shifted towards the surface, undergoing meanwhile the chemical change above spoken of. The older superficial cells are continually being removed by attrition and abrasion, while others rise up to supply their place.

The deeper layers of a stratified epithelium are not closely applied to one another by their edges, but there exists a system of intercellular

channels, which are bridged across by spikes and ridges, which project from the surfaces of the cells and abut against the corresponding spikes

Fig. 49.—Two "prickle-cells" from the deeper part of the epidermis (Ranvier).

d, space around the nucleus, probably caused by shrinking of the latter.

Fig. 49.

and ridges on the surfaces of the adjoining cells (see fig. 47). When the cells are isolated, the spikes and ridges can be better seen (fig. 49), especially if the intercellular channels have become widened in consequence of an excess of fluid accumulating in them, as may happen under certain pathological conditions.

The spikes and ridges upon the deeper cells of a stratified epithelium were first noticed by Max Schultze, who was of opinion that they were for the purpose of effecting, by indenting with those on adjoining cells, a firmer connexion between the cells of the epithelium. The true relations of the structures in question, and the intercellular channels which are bridged across by them, were discovered by Bizzozero. The researches of J. Arnold and of Thoma have shown that similar channels occur extensively in all varieties of epithelium.

Stratified scaly epithelium occurs in one of its simplest and most typical forms covering the anterior surface of the cornea of the eye (fig. 47). It is found also lining the mouth, the chief part of the pharynx, and the œsophagus, and in the female it lines the vagina and part of the cervix uteri, but its most extensive distribution is over the surface of the skin, where it forms the epidermis. In many parts of this the layers become very numerous, and their arrangement somewhat complicated, as will be noticed in the description of the skin. It may be remarked that, in most of the situations where it is found, stratified scaly epithelium is of ectodermic origin.

Transitional Epithelium.—Epithelium to which the term transitional may be applied, as being in a sense intermediate between those forms which consist of but a single layer of cells and the stratified which we have just described, may be classed under the three heads of columnar, ciliated, and scaly transitional, according to the kind of cell in each which happens to be most prominent or superficial. The columnar and ciliated transitional epithelia differ, however, so very slightly from the corresponding simple epithelia—viz., merely in the presence between the fixed ends of the columnar and ciliated cells of smaller and probably younger epithelium cells irregularly disposed—that they do not seem to merit any special description. But the scaly transitional epithelium which is met with lining the urinary bladder and ureters presents several peculiarities. It consists of three or four layers of cells, of which the inner or most superficial are large flattened scales when examined from the distended bladder (fig. 51, *a*); almost cubical in shape when taken from the collapsed organ; smooth over their free surface, but pitted on the opposite side, being moulded over the rounded ends of the cells which form the next layer. These are pyriform, and the smaller end of the pear is set upon the subjacent connective tissue, whilst the larger end has the position just mentioned (fig. 51, *b*, *c*). Filling up the intervals between these tapering cells are the smaller

irregular cells of the third layer. All these cells have distinct nuclei, and in the flattened superficial cells two nuclei may often be seen in the cell. If this, as probably is the case, is an indication that the cell is

Fig. 50. Fig. 51.

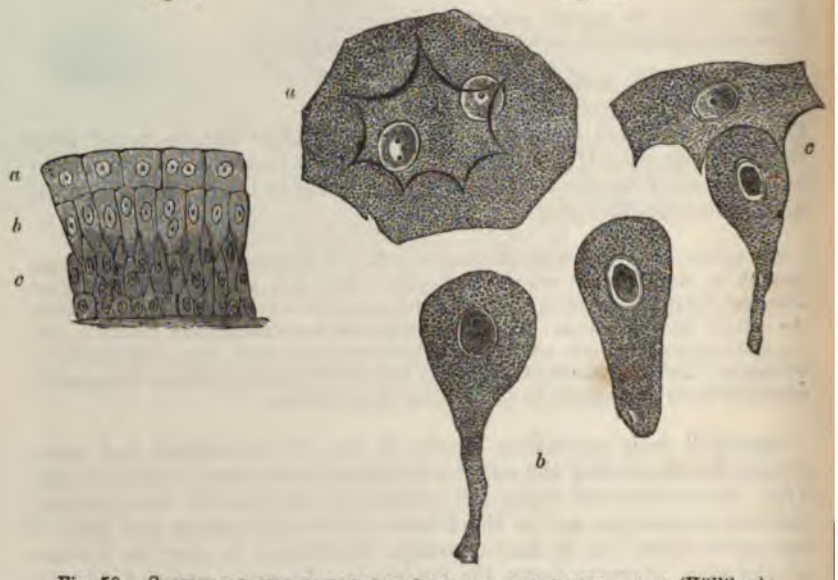


Fig. 50.—Section of the epithelial lining of the ureter; man (Kölliker).

a, superficial; *b*, intermediate; and *c*, deep layer of cells.

Fig. 51.—Epithelial cells from the bladder of the rabbit. Highly magnified. (Klein.)

a, large flattened cell from the superficial layer, with two nuclei, and with strongly marked ridges and intervening depressions on its under surface; *b*, pyriform cells of the second layer; *c*, pear-shaped cell of the second layer showing the manner in which it is adapted to a depression on the superficial cell.

about to divide, the mode of growth of this kind of epithelium must be different from that of the stratified scaly variety, in which the multiplication of the cells appears to take place exclusively in the deeper layers.

CILIATED EPITHELIUM.

In this form of epithelium, the cells which are generally columnar, bear at their free extremities little hair-like processes, which are agitated incessantly during life, and for some time after systemic death, with a lashing or vibrating motion. These minute and delicate moving organs are named *cilia*. They exist very extensively throughout the animal kingdom; and the movements which they produce are subservient to very varied purposes in the animal economy.

Distribution and use.—In the human body ciliated epithelium occurs in the following parts, viz:—1. On the mucous membrane of the air passages and its prolongations. It commences at a little distance within the nostrils, covers the membrane of the nose (except the proper olfactory part) and of the adjoining bony sinuses, and extends up into

the nasal duct and lachrymal sac. From the nose it spreads backwards a certain way on the upper surface of the soft palate, and over the upper or nasal region of the pharynx; thence along the Eustachian tube and lining membrane of the tympanum, of which it covers the greater part. The lower part of the pharynx is covered by scaly epithelium as already mentioned; but the ciliated epithelium begins again in the larynx a little above the glottis, and continues throughout the trachea and the bronchial tubes in the lungs to their smallest ramifications. Over the vocal cords, however, the epithelium is of the stratified scaly variety. 2. On the mucous lining and in the glands of the uterus, commencing at the middle of the cervix and extending along the Fallopian tubes, even to the peritoneal surface of the latter at their fimbriated extremities. 3. Lining the *vasa efferentia, coni vasculosi*, and first part of the excretory duct of the testicle. 4. To some extent on the parietes of the ventricles of the brain, and throughout the central canal of the spinal cord. 5. In the excretory ducts of certain small racemose glands of various parts (tongue, pharynx, &c.). 6. In the embryo, lining the œsophagus and parts of the stomach and extending also over the whole of the pharynx.

In other mammiferous animals, as far as examined, cilia have been found in nearly the same parts.* To see them in motion, a portion of epithelium may be scraped off from any ciliated mucous membrane and examined in a drop of weak solution of salt (·75 per cent.) or serum of blood. When it is now viewed with a magnifying power of 200 diameters or upwards, a very obvious agitation will be perceived at the edge of the detached piece of epithelium; this appearance is caused by the moving cilia, with which the surface of the membrane is covered. Being set close together, and moving simultaneously or in quick succession, the cilia, when in brisk action, give rise to the appearance of a bright transparent fringe along the margin of the membrane, agitated by such a rapid and incessant motion, that the single threads which compose it cannot be perceived. The motion here meant, is that of the cilia themselves; but they also set in motion the adjoining fluid, driving it along the ciliated surface, as is indicated by the agitation of any little particles that may accidentally float in it. The fact of the conveyance of fluids and other matters along the ciliated surface, as well as the direction in which they are impelled, may also be made manifest by immersing the membrane in fluid, and dropping on it some finely-pulverised substance (such as charcoal in fine powder), which will be slowly but steadily carried along in a constant and determinate direction; and this may be seen with the naked eye, or with the aid of a lens of low power. (Sharpey.)

The ciliary motion of the human mucous membrane is well seen on the surface of recently-extracted nasal polypi; and single ciliated particles, with their cilia still in motion, are sometimes separated accidentally from mucous surfaces in the living body, and may be discovered in the discharged mucus; or they may even be purposely detached by gentle abrasion.

Cilia have been shown to exist in almost every class of animals, from the highest to the lowest.† The immediate purpose which they serve is,

* Cilia have also been seen in some mammals at the commencement of the tubules of the kidney (Klein), a situation where in lower vertebrates they have long been known to exist.

† The Crustacea offer a singular exception, and it is remarkable that in most of them the spermatozoa are also devoid of a vibratile filament.

to impel matter, generally more or less fluid, along the surfaces on which they are attached ; or, to propel through a liquid medium the ciliated bodies of minute animals, or other small objects which are provided with cilia ; as is the case with many infusorial animalcules, in which the cilia serve as organs of locomotion like the fins of larger aquatic animals. In many of the lower tribes of aquatic animals, the cilia acquire a high degree of importance : producing the flow of water over the surface of their organs of respiration, indispensable to the exercise of that function ; enabling the animals to seize their prey, or swallow their food, and performing various other offices of greater or less importance in their economy. In man and the warm-blooded animals, their use is apparently to impel secreted fluids or other matters along the ciliated surface, as, for example, the mucus of the windpipe and nasal sinuses, which they carry towards the outlet of these cavities.

Structure.—The cells of the ciliated epithelium (fig. 52) contain oval nuclei, exhibiting for the most part a distinct intra-nuclear network,

Fig. 52.

Fig. 53.

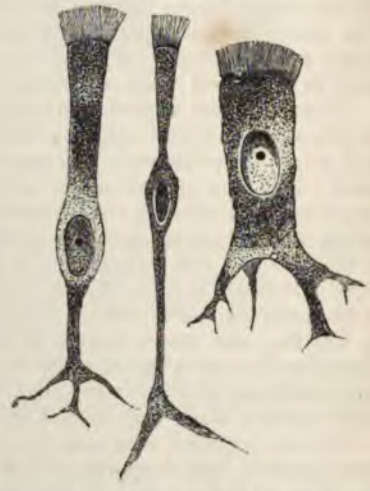


Fig. 52.—A CILIATED EPITHELIUM-CELL FROM THE TRACHEA OF THE RABBIT, ISOLATED IN VERY WEAK CHROMIC ACID ; HIGHLY MAGNIFIED (E. A. S.).

p, *p*, protoplasm of the cell, filled with clear vacuoles ; *n*, nucleus, showing nuclear membrane, nucleoplasmic network, and nucleolus ; *c*, fringe of cilia ; *b*, bright border of the cell through which the cilia pass ; *f*, fixed end of the cell.

Fig. 53.—CILIATED EPITHELIUM CELLS FROM THE TRACHEA OF THE CAT (Klein).

The fixed ends of the cells are irregularly forked.

and one or more bright nucleoli. Viewed with a moderate magnifying power, their protoplasm looks granular, but with a high power it is seen to be finely vacuolated, although the free border of the cell through which the cilia pass presents a clear aspect (fig. 46). The cells have most generally an elongated form, like the particles of the columnar epithelium, which they resemble too in arrangement, but they are often of greater length and more pointed at their lower end ; and this is not unfrequently irregularly forked in those parts where a deeper layer of cells exists below the

ciliated cells (fig. 53). The cilia are attached to their broad or superficial end, each cell bearing a tuft of these minute hair-like processes. In some cases, the cells are shorter and cubical in figure, and when completely detached may appear spheroidal, as shown in fig. 54, which represents such cells from the epithelium of the frog's mouth. In

Fig. 54.

Fig. 54.—Ciliated cells from the mouth of the frog; magnified 300 diameters (Sharpey).

rare this form occurs in the ciliated epithelium of the cerebral ventricles and that of the tympanum, where the cells form but a single stratum. The columnar ciliated epithelium may exist as a simple layer, as in the uterus and Fallopian tubes, the finest ramifications of the bronchia, and the central canal of the spinal cord: but in various other parts—as the nose, pharynx, Eustachian tube, the trachea and its larger divisions—there is a layer of elongated and irregular cells beneath the superficial ciliated range, filling up the spaces between the pointed and forked extremities of the latter. Probably the subjacent cells acquire cilia, and take the place of ciliated cells, which are cast off; but the mode of renovation of ciliated epithelium is not yet fully understood.

It is stated that when the ciliated epithelium is artificially removed from a portion of the inner surface of the rabbit's trachea, the denuded surface speedily becomes again covered with epithelium, which grows over it from the edge, but the cells form at first a single layer of flattened epithelium. They next acquire cilia, and afterwards become columnar, the epithelium thus assuming the character which it has normally in that situation.

There is no reason to believe that the ciliated epithelium cells are in connection either with nerve fibres, or with the cells of the subjacent connective tissue. It is true that such anatomical connection has been described by Lockhart Clarke and Gerlach in reference to the columnar ciliated epithelium of the central canal of the spinal cord and of the Sylvian aqueduct. But this is a most difficult point to determine exactly, and even if such a connection should be proved, the cells in the situations above mentioned are entirely different in many respects from ordinary ciliated cells. They are relatively slender, and their fixed non-ciliated ends pass into fine branching fibres, which lose themselves in a fibrillar network which underlies the epithelium, and appears to be formed chiefly, if not entirely, by the interlacement of the ramified cell-processes. These peculiar ciliated cells closely resemble those which constitute the structures known as nerve-epithelia in some of the lower invertebrata, and which in some of these represent the whole central nervous system.

Size, form and action of the cilia.—The cilia themselves differ widely in size in different animals, nor are they of equal size in all parts of the same animal. In the human windpipe they measure $\frac{1}{4000}$th to $\frac{1}{1500}$th of an inch in length; but in many invertebrate animals they are much larger than this, and in the human epididymis are from eight to ten times longer than in the trachea.

In figure they have the aspect of slender conical, or slightly flattened filaments; broader at the base, and usually pointed or rounded at their free extremity. Their substance is transparent, soft and flexible. It is to all appearance homogeneous, and no fibres, granules, or other indications of definite internal structure, have been satisfactorily demonstrated in it. According to Engelmann, cilia are doubly refracting; but this character is by no means very obvious.

In all probability the substance composing the cilia is chemically and otherwise similar to the cell-protoplasm, of which they seem to be permanent protrusions.* If this is the case, there is no difficulty in supposing that the lashing, whip-like movement of each cilium is effected by the contractility of the cilium itself, this being, however, called into action by a stimulus originating in the protoplasm of the cell to which it is attached. For if the cilia be detached they cease to move, although the isolation of the ciliated cell from its neighbours and from the other tissues does not cause a cessation of the movement. On this account it is thought, by some, that the movement is entirely a passive one, caused by the contraction of the cell-protoplasm acting upon the base of the cilium, and if this were so, there would be no need to assume that the cilia are themselves contractile. But the apparently inherent motion of the tails of the spermatozoa, which are comparable to long single cilia, and that of the long cilia which are protruded from many of the lower animal and plant organisms, seem to indicate that the movement is inherent in the cilia themselves. The cilia vibrate with a frequency of not less than ten times in a second when moving actively, but the rate of movement may be much slower than this. The movement of cilia is incessant so long as the cells remain alive, but that of spermatozoa often exhibits intervals of rest alternating with periods of rhythmic movement.

The manner in which the cilia move, is best seen when they are not acting very briskly. The motion of an individual cilium may be compared to that of a carter's whip, the cilium being rapidly flexed in one direction, that of the current, and returning more slowly to what may be regarded as the position of rest, generally a little on the other side of a plane perpendicular to the surface of the cell. The motion does not involve the whole ciliated surface at the same moment, but is performed by the cilia in regular succession, giving rise to the appearance of a series of waves travelling along the surface, like the waves caused by the wind in a field of corn. When they are in very rapid action the undulation is less obvious, and, as Henle remarks, their motion then conveys the idea of swiftly-running water. The undulating movement may be beautifully seen on the gills of a mussel. The undulations, with some exceptions, seem always to travel in the same direction on the same parts. The impulsion, also, which the cilia communicate to the fluids or other matters in contact with them, maintains a constant direction; unless in certain of the lower animals, in which the motion is often variable and arbitrary in direction, and might even be supposed to be voluntary. Thus in the windpipe of mammalia, the mucus is conveyed upwards towards the larynx, and, if a portion of the membrane be detached, matters will still be conveyed along the surface of the separated fragment in the same direction relatively to that surface, as before its separation.

The persistence of the ciliary motion for some time after death, and the regularity with which it goes on in parts separated from the rest of the body, sufficiently prove that, with the possible exceptions alluded to, it is not under the influence of the will of the animal, nor dependent for its production on the nervous centres, and it does not appear to be influenced in any way by stimulation or sudden destruction of these centres. The time during which it continues after death or separation differs in different kinds of animals, and is also materially influenced by

* According to Klein they are in continuity with the intracellular network (see fig. 38, 2.)

temperature and by the nature of the fluid in contact with the surface. In warm-blooded animals the period varies from two or three hours to two days, or even more; being longer in summer than in the cold of winter. In frogs the motion may continue four or five days after destruction of the brain and spinal cord; and it has been seen in the gullet of the tortoise fifteen days after decapitation, continuing seven days after the muscles had ceased to be irritable.

Effect of varying external conditions and reagents upon ciliary motion.—Variations of temperature exert a very marked effect upon the rate and vigour of the motion of cilia. Thus, in warm-blooded animals it is altogether stopped if the temperature is lowered to 6° C., whereas, in cold-blooded animals, such as the frog and mussel, it goes on unimpaired at 0° C. The motion which has become quiescent from cold, may be revived by warmth, and becomes more active in proportion to the rise in temperature up to a certain point, which differs in warm and cold-blooded animals. In the former, this maximum temperature is about 47° C.; above this the movement quickly ceases, the cilia passing into a coagulated stiffened condition, known as heat-rigor, and which, if well marked, is not recovered from. The temperature of the body seems to be that which is most favourable to the action of the cilia; that is to say, they will, if removed from the body, work vigorously for a longer time at this temperature than at any other.

Cilia will continue to work for a time in the absence of free oxygen. This was shown by Sharpey, who noticed the movement of the cilia upon the gill of the mussel to proceed for some hours, even when immersed in water which had been deprived of its oxygen by boiling. This experiment shows that like the substance of muscle, the protoplasm of the ciliated epithelium-cell can store up oxygen in a combined form for future use.

The immediate action of water is to increase the activity of cilia, and this is accompanied by a swelling of the cilia through imbibition of fluid. Agents or conditions, on the other hand, which abstract water from the tissue, retard or arrest the action. Thus most of the common acid and saline solutions when concentrated arrest the action of cilia instantaneously in all animals, but dilution delays this effect, and when carried far enough, prevents it altogether. Fresh water soon arrests the motion in marine animals; but it evidently acts by destroying both the form and substance of the cilia, which in these cases are adapted to a different medium. Even in air-breathing and fresh-water animals fresh water has after a time the same action, provided the ciliated cells are detached, so that it can pass by imbibition into their protoplasm. Solutions of potash or soda, if extremely dilute, act like water, but more powerfully. Virchow observed that a solution of either potash or soda would even revive the movement of cilia after it had just ceased. Narcotic substances, such as hydrocyanic acid, salts of morphia and strychnia, opium and belladonna, were stated by Purkinje and Valentin to have no effect, but the first-named agent appeared to Sharpey to arrest the motion in the river-mussel. The vapour of chloroform arrests ciliary action, but the motion revives again if the application of the vapour is discontinued (Lister).

Carbonic acid gas resembles chloroform in its action, rapidly arresting the movement if conveyed over a ciliated surface, but the action speedily recommences on again admitting air. The passage of the gas is, however, generally found to stimulate the movement at first.

Bile stops the action of cilia, while blood prolongs it in vertebrated animals; but the blood or serum of the vertebrata has quite an opposite effect on the cilia of invertebrate animals, arresting their motion almost instantaneously.

It was noticed by Steinbuch that a mechanical stimulus, insufficient to injure the cilia, such as that produced by the impulse of a current of fluid, acts markedly in exciting the activity of ciliary motion.

Electric shocks, unless they cause injury to the ciliated surface (which is sometimes the case), produce no visible effect; and the same is true of galvanic currents. Engelmann states, however, that if the ciliary action be very rapid it may be slowed, if slow it may be accelerated by electricity.

Whatever views are entertained concerning the nature and source of the power by which the cilia act, it must be borne in mind that each ciliated cell is individually endowed with the faculty of producing motion, and that it possesses in itself whatever organic apparatus and whatever physical or vital property may be necessary for that end; for single epithelium cells are seen to exhibit the phenomenon long after they have been completely isolated.

It seems not unreasonable to consider the ciliary motion as a manifestation of that property on which the more conspicuous motions of animals are known to depend, namely, vital contractility; and this view has at least the advantage of referring the phenomenon to the operation of a vital property already recognised as a source of moving power in the animal body. But, assuming this view to be sound, so far as regards the nature of the motile power brought into play, it affords no explanation of the cause by which the contractility is excited and the cilia maintained in constant action.

The first comprehensive account of the structure, distribution, and mode of action of cilia was given by Sharpey in the article "Cilia," in Todd and Bowman's Cyclopædia. That article, which appeared in 1835, was the result of much laborious investigation, and still forms the basis of our knowledge on the subject. The present account was written by Sharpey for the fifth edition of this work, and has since needed but little modification. Simultaneously with Sharpey's article a very complete description was also given by Purkinje and Valentin, including an account of the discovery of this phenomenon in mammals, birds, and reptiles, and of the literature up to that time (De phænomeno generali et fundamentali motûs vibratorii continui, 1835).

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THE CONNECTIVE TISSUES.

Three principal modifications or varieties of connective tissue have long been recognised, consisting of the same structural elements: namely, *white fibres*, *elastic fibres* and *connective tissue corpuscles*; but in widely different proportions, and thereby exhibiting a difference in their grosser or more obvious characters and physical properties. They are known as the *areolar*, the *fibrous*, and the *elastic* tissues, and will be now severally treated of. Without disregarding the alliance of cartilage and bone to the connective tissues, we shall not include them in the same general description; but there remain certain forms of tissue, occurring locally, or met with as constituents of other textures, which belong to this group, and will be briefly considered in a separate section as subordinate varieties of connective tissue.

Cartilage and bone are usually included in the group of connective tissues, and of right, for they present undoubted points of relationship with these tissues, both in their nature and the general purpose which they serve in the animal frame. Thus, yellow cartilage shows an unmistakable transition to elastic connective tissue, as fibro-cartilage does, even more decidedly, to white fibrous tissue. Moreover, the animal basis of bone agrees entirely in chemical composition, and in many points of structure, with the last-named tissue. But since both cartilage and bone possess easily recognizable histological features, besides well-marked physical and chemical characteristics, it seems more consistent with the purpose of histological description to treat of them as independent tissues.

AREOLAR TISSUE.

Distribution and arrangement.—If we make a cut through the skin and proceed to raise it from the subjacent parts, we observe that it is loosely connected to them by a soft filamentous substance of considerable tenacity and elasticity, and having, when free from fat, a white fleecy aspect; this is the substance known as *areolar tissue*. In like manner the areolar tissue is found underneath the serous and mucous membranes which are spread over various internal surfaces, and serves to attach those membranes to the parts which they line or invest; and as under the skin it is named "subcutaneous," so in the last-mentioned situations it is called "subserous" and "submucous" areolar tissue. But on proceeding further we find this substance lying between the muscles, the blood-vessels, and other deep-seated parts, occupying, in short, the intervals between the different organs of the body where they are not otherwise insulated, and thence named "intermediate;" very generally, also, it becomes more consistent and membranous immediately around these organs, and under the name of the "investing" areolar tissue, affords each of them a special sheath. It thus forms inclosing sheaths for the muscles, the nerves, the blood-vessels and other parts. Whilst the areolar tissue might thus be said in some sense both to connect and to insulate entire organs, it also performs the same office in regard to the finer parts of which these organs are made up; for this end it enters between the fibres of the muscles, uniting them into bundles; it connects the several membranous layers of the hollow viscera, and binds together the lobes and lobules of compound glands; it also accompanies the vessels and nerves within these organs, following their branches nearly to their finest divisions, and affording them support and protection. This portion of the areolar tissue has been named the "penetrating," "constituent," or "parenchymal."

It thus appears that the areolar is one of the most general and most extensively distributed of the tissues. It is, moreover, continuous throughout the body, and from one region it may be traced without interruption into any other, however distant; a fact not without interest in practical medicine, seeing that in this way dropsical waters, air, blood, and urine, effused into the areolar tissues, and even the matter of suppuration, when not confined in an abscess, may spread far from the spot where they were first introduced or deposited.

On stretching out a portion of areolar tissue by drawing gently asunder the parts between which it lies, it presents an appearance to the naked eye of a multitude of fine, soft, and somewhat elastic threads, quite transparent and colourless, like spun glass; these are intermixed with fine transparent films, or delicate membranous laminæ, and both threads and laminæ cross one another irregularly and in all imaginable directions, leaving open interstices or areolæ between them. These meshes are, of course, more apparent when the tissue is thus stretched out; it is plain also that they are not closed cells, as the term "cellular tissue" which was formerly used to denote the areolar tissue, might seem to imply, but merely interspaces, which open freely into one another: many of them are occupied by the fat, which, however, does not lie loose in the areolar spaces, but is enclosed in its own vesicles. A small quantity of colourless transparent fluid of the nature of lymph is also present in the areolar tissue, but, in health, not more than is sufficient to moisten it.

On comparing the areolar tissue of different parts, it is observed in some to be more loose and open in texture, in others more dense and close, according as free movement or firm connection between parts is to be provided for.

FIBROUS TISSUE.

When the fine bundles of connective tissue are disposed for the most part in one or two directions, instead of interlacing in every direction as in the areolar tissue, they confer a distinctly fibrous aspect to the parts which they compose, accompanied by the acquisition of certain properties, which are mainly due to the parallel disposition of the elements of the tissue, and to the preponderance of the white fibres over the elastic (see below). This *fibrous tissue* is met with in the form of ligaments, connecting the bones together at the joints; it also forms the tendons of muscles, into which their fleshy fibres are inserted, and which serve to attach these fibres to the bones. In its investing and protecting character it assumes the membranous form, and constitutes a class of membranes termed "fibrous." Examples of these are seen in the periosteum and perichondrium which cover the bones and cartilages, in the dura mater which lines the skull and protects the brain, and the fibrous layer which strengthens the pericardium, also in the albugineous coat of the testicle, and the sclerotic coat of the eye, which enclose the tender internal parts of these organs. Fibrous membranes, named "aponeuroses" or "fasciæ," are also employed to envelope and bind down the muscles of different regions, of which the great fascia inclosing the muscles of the thigh and leg is a well-known example. The tendons of muscles, too, may assume the expanded form of aponeuroses, as those of the broad muscles of the abdomen, which form strong fibrous layers in the walls of that cavity and add to their strength. It thus appears

that the fibrous tissue presents itself under two principal forms, the *fascicular* and the *membranous*.

The fibrous tissue is white or yellowish white, with a shining, silvery, or nacreous aspect. It is exceedingly strong and tough, yet perfectly pliant; but it is almost devoid of extensibility. By these qualities it is admirably suited to the purposes to which it is applied in the animal frame. By its inextensible character it maintains in apposition the parts which it connects against any severing force short of that sufficient to cause actual rupture, and this is resisted by its great strength, whilst its flexibility permits of easy motion. Accordingly the ligaments and tendons do not sensibly yield to extension in the strongest muscular efforts; and though they sometimes snap asunder, it is well known that bones will break more readily than tendons of equal thickness, and the fibrous membranes are proportionally strong and alike inextensible.

ELASTIC TISSUE.

In other situations in the body a tissue is found which, while allowing a considerable amount of extension, will readily return to its original condition when the extending force is relaxed. This is provided for by the preponderance of elastic fibres in the connective tissue, and these in the most typical examples of the tissue, such as the ligamentum nuchæ of quadrupeds and the ligamenta subflava of the human spine, give it a yellowish colour. The tissue is extensible and elastic in the highest degree, but is not so strong as ordinary fibrous ligament, and it breaks across the direction of its fibres when forcibly stretched.

Examples of the texture on a large scale are seen in the horse, ox, elephant, and other large quadrupeds, in which it forms the great elastic ligament, called *ligamentum nuchæ*, that extends from the spines of the vertebræ to the occiput, and aids in sustaining the head; in the same animals it also forms an elastic subcutaneous fascia, which is spread over the muscles of the abdomen and assists in supporting the contents of that cavity. In the human body it is met with chiefly in the following situations, viz.:—

1. Forming the *ligamenta subflava*, which extend between the arches of adjacent vertebræ; these ligaments, while they permit the bones to be drawn apart in flexion of the body, aid in restoring and maintaining their habitual approximation in the erect posture—so far, therefore, relieving the constant effort of the erector muscles. There is, moreover, an obvious advantage in having an elastic band in this situation, instead of an ordinary ligament, which would be thrown into folds when the bones are approximated. 2. Constituting the chief part of the stylo-hyoid, thyrohyoid, and cricothyroid ligaments, and those named the vocal cords. Also extending, in form of longitudinal bands, underneath the mucous membrane of the windpipe and its ramifications. 3. Entering, along with other textures, into the formation of the coats of the blood-vessels, especially the arteries, and conferring elasticity on these tubes.

MICROSCOPIC STRUCTURE OF CONNECTIVE TISSUE.

The three kinds of connective tissue, the obvious characters and arrangement of which have just been described, agree closely with one another in elementary structure. They are all composed of a matrix or ground-substance, in which cells are imbedded, and in this ground-

substance and between the cells are fibres of two kinds, the white and elastic. It is the different arrangement of the cells and fibres, as well as the relative proportion of one kind of fibre to the other, that determines the different characters of the varieties of connective tissue above enumerated.

Ground-substance and Fibres of Connective Tissue.—The **ground-substance,** matrix, or intercellular substance of the connective tissue is composed of a soft homogeneous material which occupies the tissue between the cells and cell-groups, and in which, as above stated, the fibrous elements of the tissue are found, it may be in so great a quantity as altogether to obscure the ground-substance in which they lie. It serves thus to unite the fibres, at least the white fibres, into the bundles which they form, penetrating between the individual fibrils of a bundle, and enveloping the latter with a homogeneous sheath often of great tenuity.

Fig. 55.

Fig. 55.—CELL-SPACES OF SUBCUTANEOUS CONNECTIVE-TISSUE, THE GROUND SUBSTANCE HAVING BEEN STAINED DEEPLY BY NITRATE OF SILVER. (E. A. S.) 340 DIAMETERS.

The ground-substance of connective tissue appears to contain mucin. It is precipitated and rendered cloudy by acetic acid. It becomes stained brown when treated with nitrate of silver and afterwards exposed to the light, in this respect resembling the intercellular substance of an epithelium. The cells of the tissue lie imbedded in it, either in

Fig. 56.

Fig. 56.—CELL-SPACES OF TENDON OF MOUSE'S TAIL, BROUGHT INTO VIEW BY TREATMENT WITH NITRATE OF SILVER. 175 DIAMETERS. (E. A. S.)

shallow pits on the surface, or in spaces—cell-spaces—entirely enclosed by the ground-substance, the spaces being for the most part rather larger than the contained cells, with which, however, they correspond on the whole in shape. These cell-spaces (the Saftkanälchen of Recklinghausen, lymphatic canaliculi of Klein and Burdon-Sanderson) are brought into view when the tissue is stained with nitrate of silver, for they then look white upon the brown ground (figs. 55, 56).

White Fibres.—When examined under the microscope both the areolar and fibrous tissues are seen to be principally made up of exceedingly fine, transparent, and apparently homogeneous filaments, from about $\frac{1}{3000}$ to $\frac{1}{1500}$th of an inch in thickness, or even less (fig. 57). These are seldom single, being mostly united by means of a small and usually imperceptible quantity of the ground-substance into bundles and filamentous laminæ of various sizes, which to the naked eye appear as simple threads and films. Though the bundles may intersect in every direction, the filaments of the same bundle run nearly parallel to each other, and no one filament is ever seen to divide into branches or to unite with another. The associated filaments take an alternate bending or waving course as they proceed along the bundle, but still maintain their general parallelism. This wavy aspect, which is very characteristic of these filaments, disappears on stretching the bundle, but returns again when it is relaxed.

Fig. 57.

Fig. 57.—Filaments of areolar tissue, in larger and smaller bundles, as seen under a magnifying power of 400 diameters (Sharpey).

The filaments just described, though transparent when seen with transmitted light under the microscope, appear white when collected in considerable quantity and seen with reflected light; they are doubly refracting and, therefore, appear bright when viewed between crossed Nichol's prisms. Acetic acid causes them to swell up and become indistinct. When the tissue is boiled in water the white fibres are almost wholly resolved into gelatine; they are said, therefore, to be composed of collagenous substance.

Elastic Fibres.—Occurring both in the areolar and fibrous tissue, and composing the greater part of the so-called elastic connective tissue, fibres of a different nature from those just considered are found—these are the elastic fibres. When collected in considerable quantity they have, as we have seen, a yellowish colour, but when seen singly their yellow colour does not appear; they can, however, always be recognised by the following characters. When viewed under a tolerably high magnifying power, they appear quite transparent, with a remarkably well-defined outline (fig. 58). They may run nearly straight, but often follow a somewhat bending course, with bold and wide curves, unlike the undulations of the white connective filaments. As they proceed they divide into branches, and join or anastomose together in a reticular manner (fig. 59). In some parts the elastic networks are composed of fine fibres with wide meshes; in other parts the elastic fibres are larger and broader and the

intervening spaces narrower, so that the tissue may even have a lamellar character and present the appearance of a homogeneous membrane, which may be either entire, or with gaps or perforations at short intervals, in which case it constitutes the fenestrated membrane of Henle, found in the

Fig. 58.

Fig. 59.

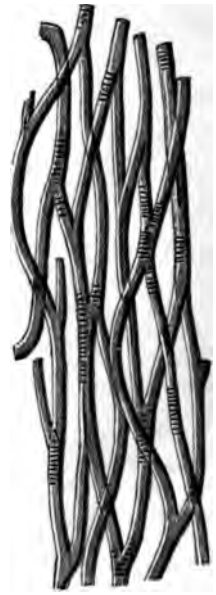


Fig. 58.—ELASTIC FIBRES FROM THE LIGAMENTA SUBFLAVA; MAGNIFIED ABOUT 200 DIAMETERS (Sharpey).

Fig. 59.—ELASTIC FIBRES FROM THE LIGAMENTUM NUCHÆ OF THE OX, SHOWING TRANSVERSE MARKINGS ON THE FIBRES; HIGHLY MAGNIFIED. (E. A. S.)

coats of the blood-vessels. A remarkable character which elastic fibres exhibit in many specimens, is a tendency to curl up at their broken ends; and these ends are not pointed, but abruptly broken across. Their size is very various; the largest in man are nearly $\frac{1}{4000}$th of an inch in diameter, the smallest perhaps not more than $\frac{1}{24000}$th. In some situations the larger sized fibres prevail; this is the case with the

Fig. 60.

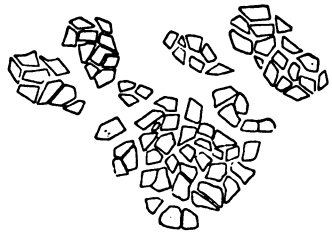
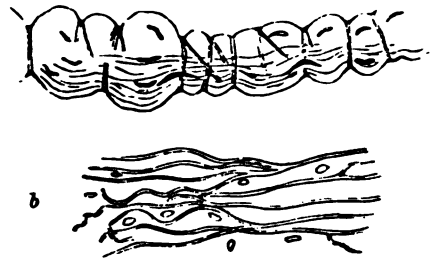


Fig. 60.—CROSS-SECTION OF ELASTIC FIBRES FROM THE LIGAMENTUM NUCHÆ OF THE OX (from a sketch by Mr. T. P. Gostling).

ligamenta subflava, where their general diameter is about $\frac{1}{1300}$th of an inch; in other instances, as in the vocal chords and in many parts of the areolar tissue, the elastic fibres are exceedingly fine. In some animals elastic fibres are met with $\frac{1}{1500}$th of an inch in thickness. In shape they are not cylindrical but angular, as is well seen in transverse section (fig. 60).

In certain portions of the areolar tissue, as for instance in that which es under the serous and mucous membranes of particular regions, the ellow or elastic fibres are abundant and large, so that they cannot well e overlooked; but in other parts and in the fibrous tissue, they are :w in number, and small, and are then in a great measure hidden by ıe white filaments; in such cases, however, they can generally be

Fig. 61.



ig. 61.—MAGNIFIED VIEW OF AREOLAR TISSUE (FROM DIFFERENT PARTS) TREATED WITH ACETIC ACID (Sharpey).

The white filaments are no nger seen, and the yellow or astic fibres with the cell-nuclei me into view. *a*, a bundle of hite fibres, which is swollen out y the effect of the acid, and pre-nts a number of constricting ands. *b* shows the branching f the nearly straight elastic fibres f areolar tissue, and their union nto a network.

endered conspicuous under the microscope by means of acetic acid, hich causes the white filaments to swell up and become indistinct, hilst the elastic fibres not being affected by that re-agent, come then ore clearly into view (fig. 61, *b*). Moreover, they resist the action of oiling alkaline solutions of potash and soda, of moderate strength, hich very speedily destroy the rest of the tissue.

A watery solution of magenta stains elastic fibres very intensely. The substance f which the elastic fibres is principally composed does not yield gelatine on boil-ıg. It has been named *elastin*, and is one of the most resistant materials met ith in the body. But it seems to be combined with some less resistant sub-ance; for Pfeuffer found that after long digestion of elastic fibres in peptic or yptic fluids, a portion of the fibre became swollen and partly dissolved, whilst he elastin remained for the most part in the form of separated particles.

Many observers have described transverse striation in elastic fibres (see fig. 59), specially in those that have been long macerated. It is not improbable that ap-earances of transverse striation, and also the tendency which the elastic fibres how to break across (seldom or never splitting longitudinally), are indications of he original formation of the fibres as rows of isolated particles, which subse-uently become fused together.

Schwalbe ascribes sheaths to the elastic fibres. Some have thought them to be ubular; but, although probably less dense at the centre than at the periphery, he fibre seems to be solid throughout.

Arrangement of the Fibres in the areolar, fibrous, and elastic issues respectively.—In the **areolar tissue** the bundles of white bres intercross in all directions (fig. 62), and exhibit every degree of urvature. The bundles are exceedingly variable in size, the number of laments in a bundle presenting a corresponding variation; and the axity or density of the tissue depends chiefly upon the size of the undles and the closeness with which they are packed.

The elastic fibres of areolar tissue run in the ground-substance between he white bundles, but when the latter are large and occupy almost the hole of the tissue the elastic fibres often appear to lie upon the surfaces f the bundles, and we even see here and there what appears to be an

elastic fibre winding round one of these bundles, and encircling it with several spiral turns. When acetic acid is applied, the fasciculus swells out between the constricting turns of the winding fibre, and presents a highly characteristic appearance (fig. 61, *a*). This remarkable disposition of the elastic fibres, which was pointed out by Henle, is not uncommon in certain parts of the areolar tissue; it may be always

Fig. 62.

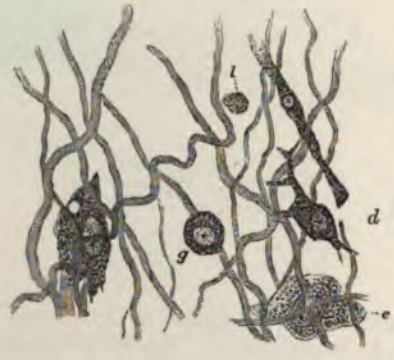


Fig. 62.—SUBCUTANEOUS CONNECTIVE TISSUE OF A YOUNG GUINEA-PIG; MAGNIFIED 350 DIAMETERS.

d, branched corpuscle; *e*, flattened corpuscle; *g*, granular corpuscle; *l*, leucocyte or migratory cell. The elastic fibres are not represented.

seen in that which accompanies the arteries at the base of the brain. It must be observed, however, that the encircling fibre sometimes forms not a continuous spiral, but several separate rings. In such a case the appearance may be explained on the supposition that the bundles in question are naturally invested with a delicate sheath (of ground-substance), which, like the elastic tissue, resists acetic acid, but, on the swelling up of the bundle under the operation of that agent, is rent into shreds or segments, mostly annular or spiral, which cause the constrictions. In other cases the union of branches of the cells around a bundle may be the cause of the appearance.

The areolæ, or interstices of the areolar tissue, are intercommunicating cleft-like spaces between the bundles and laminæ. They are not present in the immature tissue, in which the ground-substance is continuous throughout, but as the matrix becomes fibrillar the areolæ are formed, probably by the liquefaction of ground-substance.

In the **fibrous tissue** the bundles of white filaments run parallel, cohering very intimately. They either run all in one direction as in long tendons, or intersect each other in different planes as in some aponeuroses, or they take various directions and decussate irregularly with each other as in the dura mater. And when they run parallel to each other, as in tendon, they do not keep separate throughout their length, but send off slips to join neighbouring bundles and receive the like in turn; so that successive cross sections of a tendon or ligament present different figures of the sectional areas of the bundles. A sheath of dense areolar tissue covers the tendons and ligaments on the outside (fig. 63, *a*), and a variable amount of the same tissue (*d*, *e*) lies between the fasciculi into which the smaller bundles are grouped, separating them from one another, and also occurring, in greater amount, between the largest fasciculi (*c*). It is in these areolar tissue septa that the blood-vessels and lymphatics of a tendon or ligament run.

The surface of a tendon or of any other part consisting of this texture, appears marked across the direction of the fasciculi with alternate light and dark streaks, which give it a peculiar aspect, not

unlike that of a watered ribbon. This appearance is owing to the wavy course of the filaments, for when the light falls on them their bendings naturally give rise to alternate lights and shadows.

The fibrous and areolar tissues thus agreeing in their ultimate structure, it is not to be wondered at that sometimes the limits between the two should be ill-defined, and that the one should pass by inconspicuous

Fig. 63.

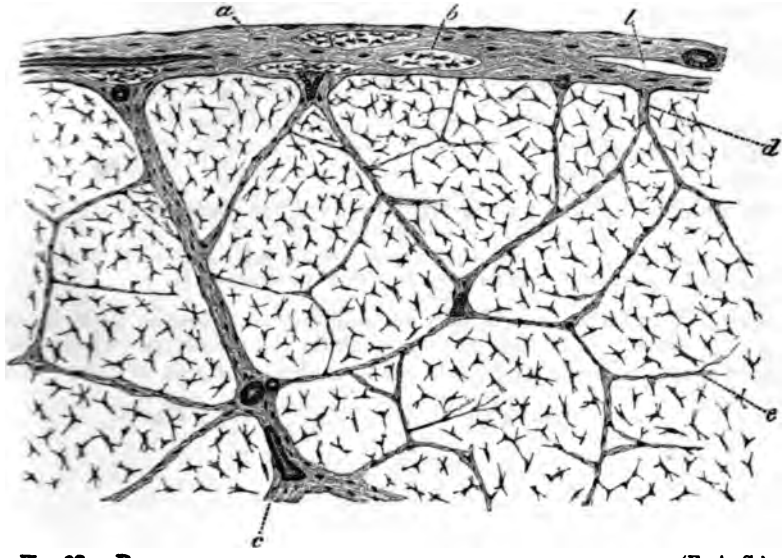


Fig. 63.—Part of a moderately large tendon in transverse section (E. A. S.)

a, areolar sheath of the tendon, with the fibres for the most part running transversely, but with two or three longitudinal bundles, *b*; *l*, lymphatic cleft in the sheath; immediately over it a blood-vessel is seen cut across and on the other side of the figure a small artery is shown cut longitudinally; *c*, large septum of areolar tissue; *d*, smaller septum; *e*, still smaller septum. The irregularly stellate bodies are the tendon cells in section.

gradations into the other. Instances of such a transition may be seen in many of the fasciæ: these at certain parts consist of dense areolar tissue, but on being traced farther are seen gradually to become fibrous; and fasciæ, which in one body are areolar in character, may be decidedly fibrous in another.

In the **elastic tissue**, there is a great proportionate development of the elastic fibres, the white bundles being relatively few and indistinct, but considerable variation is met with in the proportion of the two kinds of elements. The white bundles are, for the most part, disposed irregularly and course in different directions, as in areolar tissue; but, in some elastic ligaments, there are bundles of white fibres, which run as in an ordinary ligament parallel with one another, and from end to end of the structure. The elastic fibres in an elastic ligament, are collected into smaller and larger groups or bundles (fig. 60), which are separated from one another by septa of the white tissue, but the latter also penetrates between the individual elastic fibres of the group.

The Cells or Corpuscles of Connective Tissue.—The cellular elements of connective tissue, are mostly lamellar in shape (fig. 62, and fig. 64), and lie imbedded in the ground-substance, being often applied to the surfaces of the bundles of white fibres. Where three or more bundles come into apposition, the connective tissue cells may

Fig. 64.

Fig. 64.—Two connective tissue corpuscles from the subcutaneous connective tissue; highly magnified. (E. A. S.)

The dark streak below *l*, in the right hand corpuscle, is a lamella which happens to be projecting towards the observer and is seen in optical section.

extend between the several bundles, and they then consist of not one lamella, but of two, three, or more which fit in between the bundles, the body of the cell occupying the larger interstice. The cells in some parts,

Fig. 65. Fig. 66.

Fig. 65.—Ramified connective tissue corpuscles (E. A. S.); magnified 250 diameters.

(From a preparation stained with chloride of gold.)

Fig. 66.—Epithelioid and ramified cell-spaces of connective tissue (E. A S.). 340 diameters.

(From a preparation stained with nitrate of silver.)

The nuclei of the cells are faintly indicated.

united by their edges into patches, after the manner of an epithelium; but in other cases, the union takes place by means of branching pro-

cesses, so that the cells form a kind of network throughout the ground-substance, and a corresponding network is of course formed by the spaces in which the cells lie. These flattened connective tissue corpuscles are generally composed of comparatively clear cell-substance, with but a few granules scattered through it; they have a large oval nucleus with an intra-nuclear network and nucleoli.

According to Klein, "it can be shown that each connective tissue corpuscle is composed of two distinct substances: (*a*) a hyaline plate—*ground-plate*—which contains the oval nucleus, the substance of which is a dense network—intra-nuclear network; and (*b*) a second substance—a network of minute fibrils, *intra-cellular network*—arranged always more copiously at one side of the nucleus than at the other."

Besides these clear flattened cells, others are met with in the connective tissue, which are spheroidal and more decidedly granular, with rounder nuclei (fig. 62, *g*). Here again we must distinguish between those cells which have actual coarse granules in their protoplasm, and those the protoplasm of which is finely reticular, and merely appears granular under

Fig. 67.

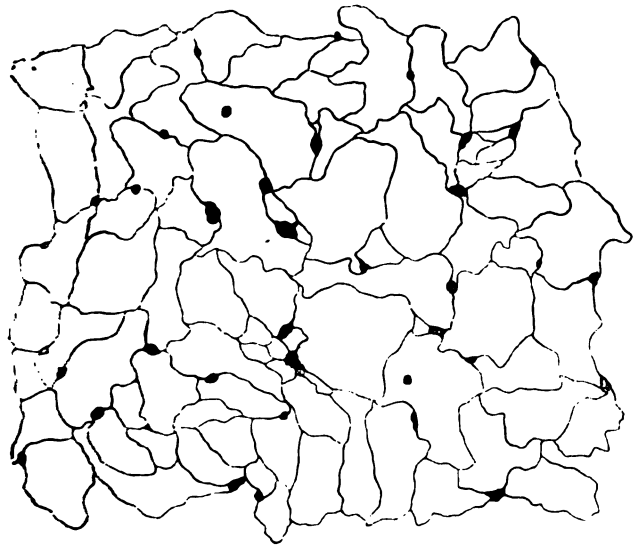


Fig. 67.—Epithelioid cells of connective tissue. From the surface of an aponeurosis treated with nitrate of silver. Highly magnified. (E. A. S.)

ordinary powers of the microscope. Although often classed together under the name of plasma-cells (Waldeyer), they are perfectly distinct elements, and it will be better therefore to reserve the name "plasma-cells" for the latter kind, especially since the reticulation of the protoplasm seems to be due to the accumulation of vacuoles containing fluid (lymph) within it, and to employ the name of granular cells for those which contain obvious granules. These are especially abundant near the blood-vessels, from which it might be inferred that they are derived from white blood-corpuscles which have migrated from the blood-vessels. Both

granular and plasma cells, are however, considerably larger than the ordinary migratory cells (fig. 62, *l*), which are also frequently met with in the connective tissue, and are known by their amœboid movement, which the connective tissue corpuscles proper do not exhibit in any appreciable degree. The plasma-cells are often irregular in shape, and may possess branching processes (fig. 62, *d*). Sometimes they are elongated into a fusiform shape, but cells of this form are not so common as was at one time supposed ; the appearance being frequently produced by flattened cells seen edge-ways.

In many membranous forms of connective tissue, the flattened cells form an epithelial-like covering to the surfaces of the membrane or membranes (fig. 67), and may even complete the latter by bridging over any gaps existing between the bundles of fibres forming the membrane. Such epithelioid tracts may be of considerable extent. It is often observable, that the cells at the margin of the patch have processes at their free border, which are connected with the ordinary scattered cells of the tissue (see fig. 66).

In **areolar tissue**, the connective tissue cells have no very definite arrangement. Both the cells and the spaces in which they lie may intercommunicate by their branches, and in this way it often happens where the tissue is thicker. that the system of cells and cell-processes, and of corresponding canals, may effect a communication between the superficial and deeper parts of the tissue. The cells of areolar tissue, are connected moreover with the flattened cells which line the smaller blood-vessels and lymphatics, and by means of this connection, and the continuity of the cell-spaces of the tissue, channels are provided for the flow of blood-plasma from the blood-vessels or towards the lymphatics. In addition to this, no doubt some of the plasma or lymph may soak through the ground-substance, or find its way through the lacunar interstices (areolæ) of the tissue.

Fig. 68.

Fig. 68.—Tendon of mouse's tail, stained with logwood; showing chains of cells between the tendon-bundles. 175 diameters. (E. A. S.)

In **fibrous tissue**, (tendon and ligament), the cells, which are often called "tendon-cells," follow the parallel arrangement of the fibre-bundles, and are disposed in rows or chains (fig. 68), which may be easily seen if a very fine tendon, such as those in the tail of the mouse or rat, or a portion only of a larger one is examined under the microscope, and a little dilute acetic acid is cautiously added. A peculiar shape is impressed upon these cells by the close packing of the tendon bundles, for although they may look quadrangular or oblong when the tendon is viewed longitudinally (figs. 68, 69), yet when it is cut across, they have a stellate appearance (figs. 63, 70), for like other flattened connective tissue cells,

ey send lamellar extensions into the interstices between the contiguous ndles, whilst the middle of each cell, containing the nucleus, lies in the

Fig. 69.

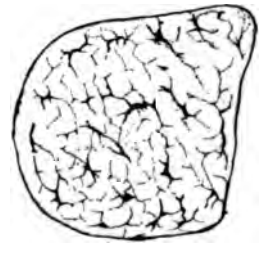
Fig. 69.—Eight cells from the same tendon as represented in Fig. 68. Magnified 425 diameters. (R. A. S.)

he nuclei, with their numerous nucleoli, were deeply coloured by the logwood. The t lines on the surface of the cells are the optical sections of lamellar extensions directed rds or away from the observer.

gular space between three or more bundles. When the tendon-cells viewed longitudinally, any of the lamellar extensions, which are ected either towards or away from the observer, appear as lines on the face of the cell (fig. 69). The same appearance is often seen upon the tened cells of the denser forms of areolar tissue, where the cells have en squeezed in between three or more bundles.

Each tendon-cell consists of a delicate protoplasmic body, thicker at the ntre and thinning off in the extensions, and containing a flattened, nd or oval, clear nucleus, with several nucleoli. The ends of adjacent

Fig. 70.



g. 70.—Transverse section of tendon of mouse's tail stained with logwood. 175 diameters. (R. A. S.)

The flattened processes of the tendon-cells (which are ined deeply by logwood) appear in section as lines, fre-ntly coming off at right angles from the body of the L. The bundles of fibres are not represented; they very irregular, and but incompletely separated by the l-processes.

lls are in close apposition, and form, as before ticed, long chains of cells in the tendon, and e nucleus is generally so situated towards ie end of the cell as to be in close proximity to the nucleus of an ad-cent cell; they thus present the appearance of being arranged in irs (fig. 69). Here and there a third nucleus, with a small amount of otoplasm, may be seen interpolated between two such cells.

The lamellar extensions of the cells do not always end with an even e, but are themselves often prolonged into fine branches, which pene-te still further into the ground-substance which separates the fibre-ndles of the tendon from one another.

In the **pure elastic tissue**, such as that which constitutes the gamentum nuchæ in animals and the ligamenta subflava in man, is generally stated that cells are altogether absent. Schwalbe finds the contrary numerous flat connective tissue cells scattered in the ound-substance which lies between the elastic fibres; the cells being ten in close apposition with the elastic fibres, but never in continuity ith them, as was described by Thin.

Vessels and Nerves of Connective Tissue.—Although blood-vessels, lymphatics, and nerves are everywhere conveyed in the **areolar tissue** to the places where they are to be distributed, very few blood-capillaries are destined for the tissue itself, although abundant lymphatic networks are present in many parts; especially in the subcutaneous, subserous and submucous tissues. It is uncertain whether nerves terminate in the areolar tissue. It may be cut in a living animal apparently without giving pain, except when the instrument meets with those branches of nerves which traverse the tissue on their way to other parts.

The **fibrous tissue** receives blood-vessels, but in general they are inconsiderable both in number and size compared with the mass of tissue to which they belong. In tendons and ligaments with longitudinal fasciculi, the chief branches of the vessels run parallel with and between the larger fasciculi, and, sending communicating branches across them, eventually form a very open network with large oblong meshes. Some fibrous membranes, as the periosteum and dura mater, are much more vascular; but the vessels seen in these membranes do not strictly belong to them, being destined for the bones which they cover.

Lymphatics are contained in great abundance, as Ludwig and Schweigger-Seidel showed, in the enveloping areolar-tissue sheaths of tendons and aponeuroses, where they form plexuses with polygonal meshes. In addition to these, a close network of lymphatic vessels with elongated meshes may be injected in the deeper parts of the tendons, where they run in the penetrating areolar tissue. Sometimes, as in the central tendon of the diaphragm, lymphatic spaces separate the tendon bundles from one another. A connection no doubt subsists between these lymphatics and the cell-spaces of the fibrous tissue: and it has been suggested that the lymphatic vessels of the tendons are partly concerned in the removal of lymph from the muscles, in which the existence of lymphatic vessels has not hitherto been recognized.

The penetrating areolar tissue of tendons, like the same tissue elsewhere, possesses areolæ, which here take the form of elongated clefts, and these may also partly serve for the passage of lymph.

Many tendons and ligaments, and some fibrous membranes, have been shown to possess nerve-fibres, which course for the most part in a direction parallel with the fasciculi and may terminate in a special manner within these tissues, as will be noticed when the peripheral distribution of nerves is described.

As to **elastic tissue**, the yellow ligaments, which contain this in its purest form, are but scantily supplied with blood-vessels, those that are present running in the interstitial areolar tissue between the elastic bundles. The lymphatic vessels also course for the most part longitudinally in the interstitial areolar tissue, being connected here and there by transverse branches, and in addition to these vessels the lymph may be conveyed by means of the elongated areolæ of the same tissue. Neither blood-vessels nor lymphatic vessels actually penetrate into the small bundles of elastic fibres, although the lymphatic vessels often lie close against the surface of the bundles.

SPECIAL VARIETIES OF CONNECTIVE TISSUE.

1.—At an early period of development connective tissue consists of a pellucid jelly and nucleated corpuscles. The soft watery jelly contains the chemical principle of mucus, or *mucin*, and, in much less proportion, *albumin*, but not gelatin. In the general course of development of the tissue, fibres, both white and elastic, are formed in the soft matrix, and finally obscure or obliterate this substance in a great measure. But in certain cases the course is different. The cells may disappear, only the jelly remaining, as in the vitreous humour of the eye; or the corpuscles

Fig. 71.

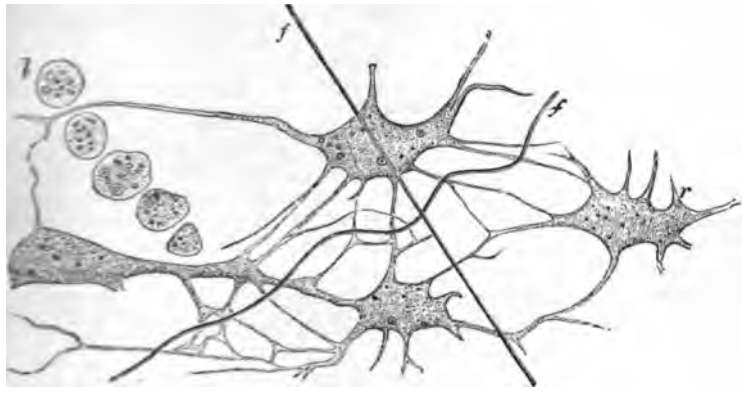


Fig. 71.—JELLY OF WHARTON (Ranvier)

r, ramified cells intercommunicating by their branches; *l*, a row of leucocytes or migratory cells; *f*, *f*, fibres coursing through the ground-substance.

may branch out and join together in form of a network in the jelly, with the nuclei persisting at the spots whence the threads diverge. The areolar tissue surrounding and imbedding the vessels in the umbilical cord of the fœtus consists of fusiform and ramified corpuscles associated with white fibrillar bundles and elastic fibres, along with a quantity of the original soft matrix, which is persistent at the time of birth. The tissue is here known as the jelly of Wharton (fig. 71).

Connective tissue of this nature is known as **jellylike** or **mucous tissue**.

2.—In other cases the matrix disappears or liquefies: and the ramified corpuscles unite together into a reticular or fine trabecular structure (fig. 72): either retaining their nuclei as at *a*, or losing them and then forming a fine network of simple fibres without nuclei as at *b*. Sometimes the processes of the cells are flattened out, and then sections of the tissue have a somewhat honeycombed appearance.

That the tissue is constructed of ramified corpuscles is shown by its withstanding boiling in water, whilst it readily dissolves in hot alkaline solutions, whereas if the fibres composing the network were of the white or of the elastic variety, they would behave differently under such treatment. Nevertheless as Bizzozero has pointed out, the branched

cells of this tissue are, in some situations at least, if not in all, wrapped round small anastomosing bundles of connective tissue fibres.

To a tissue which is thus formed of branched cells united into a network, the term **retiform or reticular tissue** is applied: it is also known as **adenoid tissue.**

Fig. 72.

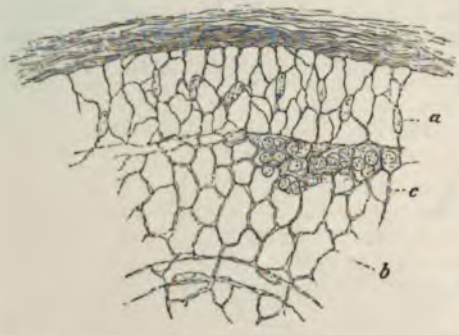


Fig. 72.—THIN SECTION FROM THE CORTICAL PART OF A LYMPHATIC GLAND, MAGNIFIED. (His.)

a, *b*, network of fine trabeculæ formed by retiform or adenoid tissue, from the meshes of which the lymph-corpuscles have been washed out, except at *c*, where they are left.

In many situations the meshes of the retiform tissue are occupied by numerous corpuscles which closely resemble the pale blood- or lymph-corpuscles, but have a relatively larger nucleus, and less protoplasm than those. They are known as *lymphoid cells*, and the tissue containing them is termed **lymphoid or lymphatic tissue.** In this form, retiform tissue is found composing the greater part of the lymphatic glands, and other structures allied to them, such as the solitary and agminated glands of the intestine, and the similar structures in the tonsils and elsewhere. Moreover, the alimentary mucous membrane is in great measure composed of the same tissue, and it occurs also in other mucous membranes and, in the form either of elongated tracts or of isolated nodules, in many parts of the serous membranes. In the spleen, the interstices of the retiform tissue are for the most part occupied by blood, instead of by lymph as elsewhere. In organs into the construction of which this tissue enters, it serves as a supporting framework to those parts of the organ into which connective tissue of the ordinary kind does not penetrate.

3.—Another special variety of connective tissue is met with in the form of delicate membranes, and was formerly supposed to be quite homogeneous in structure. These membranes have, however, in many cases been shown to be made up of flattened cells, in close apposition, which can be brought to view by staining with nitrate of silver. This is the case with the so-called **basement membranes** or **membranæ propriæ**, which are found under the epithelium of many mucous membranes, and outside the epithelium of secreting glands. They form therefore examples of an epithelioid arrangement of connective tissue cells. In other cases the membranes in question are of an elastic nature, *e. g.* the posterior elastic lamina of the cornea.

DEVELOPMENT OF CONNECTIVE TISSUE.

Those parts of the early embryo in which connective tissue is subsequently to be developed, are at first composed entirely of embryonic cells, to all appearance similar to those which constitute the mesodermic layer generally. The [illegible] of importance that occurs is the development of blood-vessels

from some of these cells in the manner that has already been partly explained (p. 34), and will be further treated of when those vessels have come under consideration. Soon after the development of these primitive blood-vessels the embryonic cells become more separated, but retain for the most part a connection with one another by interjoining processes; and the interstices between the cells are now found to be filled with a clear fluid, which is either produced by the cells themselves, or derived directly by transudation from the blood-vessels. This mucoalbuminous fluid subsequently acquires a firmer consistence, and eventually remains as the ground-substance.

In this ground-substance fibres become developed of the two kinds, white and elastic, but the manner in which they are formed is by no means clear; and two distinct and opposed views are held by histologists upon the subject. According to the one view, the bundles of white fibrils are produced by a direct conversion of the protoplasm of some of the cells, the others remaining as the permanent connective tissue corpuscles; or it may be that some of the latter represent embryonic cells, layers of whose protoplasm have been successively converted into fibrillar tissue, the cells, meanwhile, after each such conversion, growing again to their original size, and at length remaining in contact with the bundle of fibres which they have assisted to form. Similarly the elastic fibres are believed to be formed of the processes of some others of the embryonic cells, which become connected with processes from other cells, and undergoing a chemical transformation, produce the networks of elastic fibres. According to the other view the fibres, both white and elastic, are formed by a deposit in the intercellular substance, and not by a direct change of the protoplasm of the cells, with which indeed they are not connected; although it is not impossible that the deposition may in some way or other be influenced, or even caused by the pre-existing cells.

In favour of this latter view may be instanced the jelly of Wharton, which is merely connective tissue in a particular phase of development, and in which the fibres of both kinds can be seen coursing through the jelly-like intercellular substance, apart entirely from the cells (see fig. 71, *f*). And further it may be mentioned that, when white fibres of connective tissue are developed in cartilage, it is in the intercellular substance that they appear, and, so far as can be seen, they are quite unconnected with cells. In the case of the elastic fibres, these, as shown by Ranvier, first appear in the form of rows of granules or globules, which subsequently become fused together end to end, and are not at any time connected with cells (Fig. 73). To form an elastic membrane, in place of being arranged in lines the globules are deposited in small patches, and by their fusion the membrane is formed (*p*). In elastic cartilage the granules first make their appearance, it is true, in the immediate neighbourhood of the cartilage-cells; but although this renders it probable that the deposition of the granules is influenced by the cells, it does not prove that they are formed by a direct conversion of the cell-protoplasm. Indeed, the subsequent extension of the fibres into those parts of the matrix which were previously clear of them, and in which no such direct conversion of

Fig. 73.

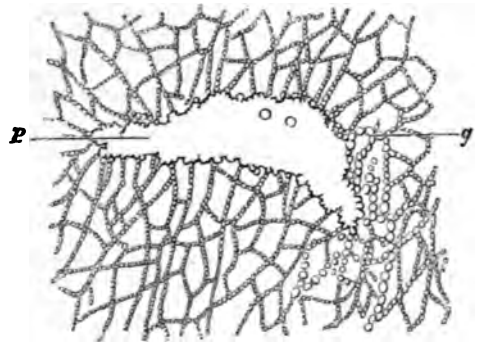


Fig. 73. — DEVELOPMENT OF ELASTIC TISSUE BY DEPOSITION OF FINE GRANULES (RANVIER).

g, moniliform fibres formed of rows of "elastin" granules; *p*, flat platelike expansion of elastic substance formed by the fusion of "elastin" granules.

cell-protoplasm seems possible, is a strong argument in favour of the deposition hypothesis.

The view which supposes that a direct conversion of the protoplasm of the connective tissue cells takes place into fibres, both white and elastic, has of late years been widely adopted, but it seems to rest less upon observation than upon a desire to interpret the facts in accordance with the conceptions of Beale and M. Schultze, according to which every part of an organised body consists either of protoplasm (formative matter), or of material which has been protoplasm (formed material), and the idea of a deposition or change occurring outside the cells in the intercellular substance is excluded. But it is not difficult to show that a formation of fibres may occur in soft substances in the animal organism, independently of the direct agency of cells, although the materials for such formation may be furnished by cells. Thus in those cœlenterate animals in which a low form of connective tissue first makes its appearance, this is distinguished by a total absence of cellular elements, the ground-substance being first developed and fibres becoming formed in it. Again, the fibres of the shell-membrane of the bird's egg are certainly not formed by the direct conversion of the protoplasm of the cells which line the oviduct, although it is probably in matter secreted by those cells, and through their agency, that the deposit occurs in a fibrous form.

The formation of the special varieties of connective tissue has already been considered (see p. 69).

Regeneration.—Connective tissue appears to be readily regenerated, although the new cicatricial tissue which is formed in place of that which has been removed by the knife or by disease, is not always of the same character, either as regards its cells or fibres, as the tissue it replaces. In the course of time the new tissue may assimilate itself somewhat to the old, but seldom to such an extent that the scar cannot be detected.

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ADIPOSE TISSUE.

The human body in the healthy state contains a considerable amount of fatty matter of different kinds. It exists in several of the secretions—in some constituting the chief ingredient; and it enters into the composition of many of the textures. But by far the greater part of the fat of the body is inclosed in small cells or vesicles, which, together with their contained matter, constitute the adipose tissue.

Distribution.—This tissue is not confined to any one region or organ, but exists very generally throughout the body, accompanying the still more widely distributed areolar tissue in most, though not in all parts in which the latter is found. Still its distribution is not uniform, and there are certain situations in which it is collected more abundantly. It forms a considerable layer underneath the skin, and, together with the subcutaneous areolar tissue in which it is lodged, constitutes in this situation what has been called the *panniculus adiposus*. It is collected in large quantity round certain internal parts, especially the kidneys. It is seen filling up the furrows on the surface of the heart, and imbedding the vessels of that organ beneath its serous covering; and in various other situations it is deposited beneath the serous membranes, or is collected between their folds, as in the mesentery and omentum, at first generally gathering along the course of the blood-vessels and at length accumulating very copiously. Collections of fat are also common round the joints, lying on the outer surface of the synovial membrane, and filling up inequalities; in many cases lodged in folds of the

Fig. 74.

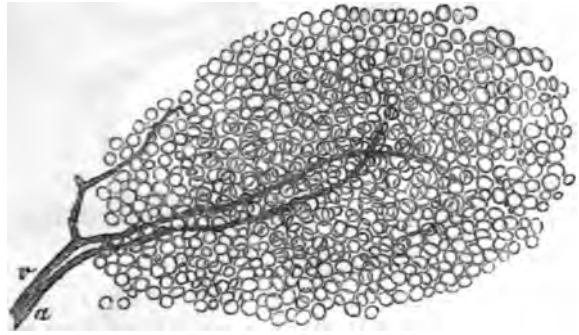


Fig. 74. A SMALL FAT-LOBULE FROM THE SUBCUTANEOUS TISSUE OF THE GUINEA-PIG, MAGNIFIED ABOUT 20 DIAMETERS. (E. A. S.)

a, small artery distributed to the lobule; *v*, small vein; the capillaries within the lobule are not visible.

membrane, which project into the articular cavity. Lastly, the fat exists in large quantity in the marrow of bones. On the other hand, there are some parts in which fat is never found in the healthy condition of the body. Thus it does not exist in the subcutaneous areolar tissue of the eyelids and penis, nor in the lungs except near their roots, nor within the cavity of the cranium.

Structure.—When subjected to the microscope, the adipose tissue is seen to consist of small vesicles, filled with an oily matter, and for the most part lodged in the meshes of the areolar tissue. The vesicles are most commonly collected into little lobular clusters (fig. 74), and

these again into the little lumps of fat which we see with the naked eye, and which in some parts are aggregated into round or irregular masses of considerable magnitude. Sometimes the vesicles, though grouped together, have less of a clustered arrangement; as when they collect alongside of the minute blood-vessels of thin membranous parts.

In well-nourished bodies the vesicles or fat-cells are round or oval (fig. 75), unless where packed closely together, in which case they acquire an angular figure, and bear a striking resemblance to the cells of vegetable tissues. The greater number of them are from $\frac{1}{300}$th to $\frac{1}{600}$th of an inch in diameter, but many exceed or fall short of this measurement. Each one consists of a very delicate envelope (*m*), inclosing the oily matter, which, completely filling the envelope, appears as a single drop (*f*, *g*). It often happens that a part of the fatty contents solidifies in the cell after death, forming a bunch of delicate needle-shaped crystals (fig. 75, *c r*).

The envelope is the remains of the original protoplasm of the cell: it

Fig. 75.

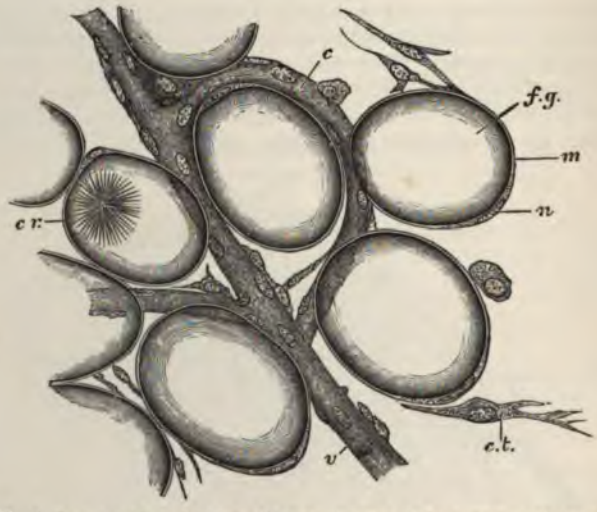


Fig. 75. A FEW CELLS FROM THE MARGIN OF THE FAT-LOBULE REPRESENTED IN THE PRECEDING FIGURE: HIGHLY MAGNIFIED. (E. A. S.)

f g, fat globule distending a fat-cell; *n*, nucleus; *m*, membranous envelope of the fat-cell; *c r*, bunch of crystals within a fat-cell; *c*, capillary vessel; *v*, venule; *c t*, connective tissue cell; the fibres of the connective tissue are not represented.

is generally quite transparent, and apparently homogeneous. According to some authorities it consists of two parts, a delicate structureless external membrane, and a layer of finely granular protoplasm immediately surrounding the fat. The nucleus (*n*) is always present in the protoplasm, but is often so flattened out by the pressure of the inclosed oil-drop as to be visible only with difficulty.

The areolar tissue connects and surrounds the larger lumps of fat, but forms no special envelope to the smaller clusters; and although fine fasciculi and filaments of that tissue pass irregularly over and through the clusters, yet it is probable that the vesicles are held together in these

groups mainly by the fine network of capillary vessels distributed to them. In the marrow the connective tissue fibrils are but few in number or may, it is said, be absent altogether.

The adipose tissue is copiously supplied with **blood-vessels**. The larger branches of these pass into the fat-lumps, where they run between the lobules and subdivide, till at length a little artery and vein are sent to each small lobule (fig. 74, *a*, *v*), dividing into a network of capillary vessels, which pass between the vesicles in all directions, supporting and connecting them. The **lymphatics** of the fat are in close relation to the blood-vessels, accompanying and occasionally completely enclosing them as they enter the lobule. No nerves have been seen to terminate in this tissue, although nerves destined for other textures may pass through it. Accordingly it has been observed that, unless when such traversing nervous twigs happen to be encountered, a puncturing instrument may be carried through the adipose tissue without occasioning pain.

Development.—The fat first appears in the human embryo about the fourteenth week of intra-uterine life. It is deposited in the form of minute granules or droplets in certain cells of the connective tissue (figs. 76, 77, *f*, *f'*): these droplets increase in size, and eventually run together, so as to form one large drop in each cell. By further deposition the cell becomes swollen out to a size far beyond that which it possessed originally, and its protoplasm remains as a delicate envelope surrounding the fat-drop. By the end of the fifth month the fat-cells have largely increased in number, and have become collected into small groups.

Fig. 76.

Fig. 76.—Deposition of fat in connective tissue cells of the new-born rat. (E. A. S.)

f, *f'*, fat cells; *h*, hæmapoietic cell.

The deposit of fat within the cells is preceded and accompanied by the formation of a rich network of capillary blood-vessels (fig. 77), which are produced by a transformation of other cells of the tissue in the manner previously described (p. 34).

Fig. 77.

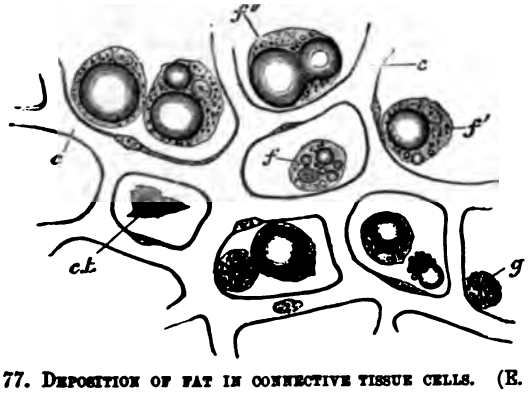


Fig. 77. Deposition of fat in connective tissue cells. (E. A. S.)

f, a cell with a few isolated fat-droplets in its protoplasm; *f'*, a cell with a single large and several minute drops; *f''*, fusion of two large drops; *g*, granular cell, not yet exhibiting any fat deposition; *c t*, flat connective tissue corpuscle; *c*, *c*, network of capillaries.

The fat is often deposited in the granular cells of the connective tissue, these being usually found in great abundance in those situations in which fat is becoming developed (fig. 77). Sometimes, however, the deposition takes place in the more ordinary connective tissue cells (fig. 76, *f*), or in cells which are apparrently intermediate between these and the granular cells, being rounded like the latter, but consisting of a much clearer protoplasm (fig. 76, *f'*). When deposited in ramified or flattened cells these acquire a spherical shape as they enlarge, in consequence of the distension produced by the accumulating fat.

The fat in some parts, and especially in the serous membranes, is formed at the expense of pre-existing lymphatic tissue, the lymphoid cells probably becoming enlarged and transformed into fat cells, whilst a considerable development of blood-vessels accompanies the change. A similar transformation is also witnessed in the thymus gland, which, in the fœtus and infant, is chiefly composed of lymphoid tissue, but as growth proceeds becomes wholly converted into a mass of fat.

The superficial resemblance which adipose tissue often bears to many glands, in its lobulated structure and the arrangement of its blood-vessels, has led some histologists to look upon the fat-cell as a corpuscle of specific nature, and totally distinct from any other kind of cell met with in the connective tissue. But against this view it may be urged that the situations in which fat is deposited are, previously to its appearance, in no way distinguishable from the rest of the areolar tissue; that the cells in which it is produced are, so far as can be seen, the same as those which are met with in almost all parts of the areolar tissue; and further, that when from any natural cause the fat is entirely removed from the cells of a part and not again deposited in them, the part eventually acquires all the ordinary characteristics of the areolar tissue. The great development of blood-vessels in adipose tissue is obviously related to the function which it subserves in storing up the fatty materials derived from the food in such a form and situation as to be readily re-absorbed into the circulation when needed. Moreover, fat may be deposited in other kinds of connective tissue than the areolar, and even in the cells of some epithelia.

PIGMENT.

An accumulation of coloured pigment-granules is met with in many cells of the animal body, but most frequently in epithelium-cells and in cells belonging to the connective tissue. A well-marked example of pigmented epithelium-cells in the human body is afforded by the black coating which forms the external layer of the retina of the eye, and covers the posterior surface of the iris. Dark pigment is also met with in

Fig. 78.

Fig. 78.—RAMIFIED CELLS, FROM THE TISSUE OF THE CHOROID COAT OF THE EYE; MAGNIFIED 350 DIAMETERS (Kölliker).

a, cells with pigment; *b*, colourless fusiform cells.

the deeper layers of the cuticle, especially in the coloured races, and in certain epithelial cells of the membranous labyrinth of the ear, and the olfactory region of the nose (combined in the latter case with brownish yellow pigment).

In the connective tissue the pigment is met with in enlarged and irregularly branched corpuscles which are termed **pigment-cells.** Such ramified cells are very common in many animals. In the human body cells of this description are found in the dark tissue on the outer surface of the choroid coat, (fig. 78, *a a*), in the iris, where they are often variously coloured, and on the pia mater covering the upper part of the spinal cord. Pigment is also found in some of the

ramified cells which form part of the retiform tissue of the medullary substance of lymphatic glands, and occasionally in some of the similar cells of the spleen. It may also be seen in migratory cells, but this is more common in pathological conditions.

The pigment, strictly so called, which is contained within the cells, consists of black or brown granules or molecules of a round or oblong shape, and almost too small for exact measurement. These molecules are densely packed together in some cells; in others they are more scattered, and then it may be seen that there is a certain amount of colourless matter included along with them. When they escape from the ruptured cells, they exhibit very strikingly the "Brownian" molecular movement; and in consequence of this movement the apparent figure of the particles is subject to change. It is worthy of remark, that when viewed singly with a very high magnifying power they look transparent and almost colourless, and it is only when they are heaped together that their dark colour distinctly appears. The nucleus of the pigment-cell is not coloured, but is very often hidden from view by the black particles.

In the lower animals remarkable movements are often observed in the ramified pigment-cells, *e.g.*, those of the frog's skin. In these the dark particles of pigment are at one time dispersed through the whole cell and its branches, but at another time they gather into a heap in the central part, leaving the rest of the branched cell vacant, but without alteration of its figure. In the former case the skin is of a dusky hue; in the latter, pale. The aggregation of the pigment-molecules can be excited through the nerves, both directly and also in a reflex manner, as by the stimulus of light upon the retina.

CARTILAGE.

This is the well-known substance commonly called "gristle." The following are its more obvious characters. When in mass, it is opaque and of a pearly or bluish white colour, in some varieties yellow; but in thin slices it is translucent. Although it can be easily cut with a sharp knife, it is nevertheless of very firm consistence, but at the same time highly elastic, so that it readily yields to pressure or torsion, and immediately recovers its original shape when the constraining force is withdrawn. By reason of these mechanical properties, it serves important purposes in the construction of some parts of the body.

In the early embryo the skeleton is, in great part, cartilaginous; but the cartilage forming its different pieces, which have the outward form of the future bones, in due time undergoes ossification or gives place to bone, in the greater part of its extent at least, and hence this variety of cartilage is named "temporary."

Of the permanent cartilages a great many are in immediate connection with bone, and may be still said to form part of the skeleton. The chief of these are the articular and the costal cartilages; the former cover the ends or surfaces of bones in the joints, and afford these harder parts a thick springy coating, which breaks the force of concussion and gives ease to their motions; the costal or rib-cartilages form a considerable part of the solid framework of the thorax, and impart elasticity to its walls. Other permanent cartilages enter into the formation of the external ear, the nose, the eyelids, the Eustachian

tube, the larynx, and the windpipe. They strengthen the substance of these parts without undue rigidity; maintaining their shape, keeping open the passages through them where such exist, and giving attachment to moving muscles and connecting ligaments.

Cartilages, except those of the joints, are covered externally with a vascular fibrous membrane named the *perichondrium*.

When a very thin slice of cartilage is examined with the microscope, it is seen to consist of nucleated cells, disseminated in a solid mass or matrix (fig. 80). The matrix is sometimes transparent, and to all appearance homogeneous; sometimes dim and very faintly granular, like ground glass: both these conditions occur in *hyaline cartilage*, which may be regarded as the most typical form of the tissue. Two varieties exist in which the matrix is pervaded to a greater or less extent by fibres. In the one named *elastic* or *yellow fibro-cartilage*, the fibres are similar to those of elastic tissue; in the other, named *white fibro-cartilage*, they are of the white kind as in ordinary ligament.

HYALINE CARTILAGE.

Structure.—In hyaline cartilage the matrix, as just stated, is uniform, and, when examined fresh, usually appears free from fibres. Like the ground-substance or matrix of connective tissue, it becomes stained brown by nitrate of silver and subsequent exposure to the light. The cells consist of a rounded, oval, or bluntly angular *cell-body* of

Fig. 79.

Fig. 79.—A CARTILAGE CELL IN THE LIVING STATE, FROM THE SALAMANDER. HIGHLY MAGNIFIED (Flemming).

translucent protoplasm, embedded in which are fine curvilinear interlacing filaments and minute granules (fig. 79), with a round *nucleus*, which is either clear with one or more *nucleoli*, or, more commonly, is occupied by a network of nucleoplasm, which produces under a low power of the microscope a granular effect. The cell-body lies in a cavity of the matrix, which, in its natural condition, it entirely fills. This cavity is bounded and inclosed by a transparent *capsule*, which is seldom obvious to the eye, for it coheres intimately with the surrounding matrix, with which it agrees in nature, and cannot usually be distinguished without the aid of re-agents.

By exposure to water and some other liquids, as well as to the action of electric shocks, the cell-body shrinks away from the inside of the capsule, and assumes a jagged or otherwise irregular figure, and then may hide the nucleus (fig. 82). It often contains larger or smaller fat-globules (fig. 80, *g*).

The cells of cartilage appear to contain glycogen, for they are coloured reddish brown by iodine (Neumann).

They are rarely dispersed singly in the matrix; most commonly occurring in groups of two or more. When disposed in pairs (as at *a*, fig. 80) the cells are generally triangular or pyramidal in form with rounded angles, and with their bases opposite one another; in the larger groups (*b*) the cells have a straight outline where they adjoin or approach one another, but at the circumference of the group their outline is rounded. Towards the surface of the cartilage the groups are

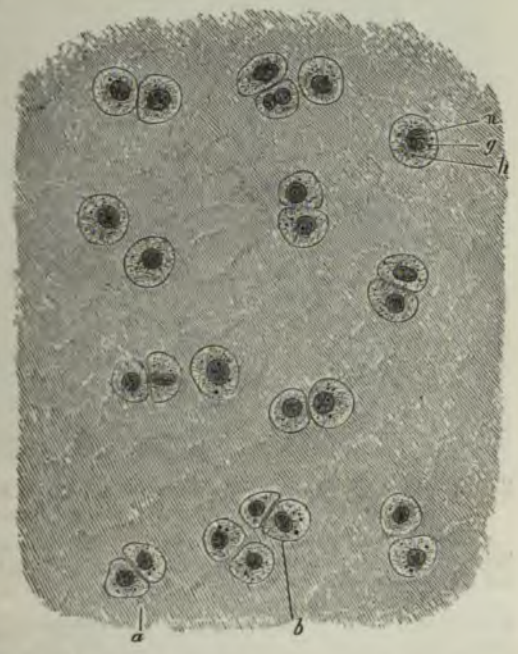
ly flattened conformably with the surface, appearing narrow and linear when seen edgeways, as in a perpendicular section , *a*).

is observers, and especially Tillmanns, have shown that the matrix of cartilage can be broken up after long maceration, and with the aid of , into fine fibrils. According to Cresswell Baber, these fibres are vertical

—ARTICULAR CAR- FROM HEAD OF ARSAL BONE OF MAN ACID PREPARA- THE CELL-BODIES LY FILL THE SPACES MATRIX. 340 DIA- . (E. A. S.)

up of two cells; of four cells; *h*, m of cell, with *g*, nules; *n*, nucleus.

Fig. 80.



rface in articular , and parallel with axis in rib car- Their chemical is not, however, r, nor is it certain the appearances nd with any struc- turally present; Kühne and Mero- assert, gelatin in can be obtained e matrix of carti- fibres in question chemically of the ture as the white f connective tis- mucin belonging round-substance in which they are embedded.

histologists have described a network of exceedingly fine ramified canals ing the cartilage matrix, and effecting a communication between the es. Up to the present time, however, the existence of such anastomosing s has not been conclusively proved, although often assumed in order to ex- e manner in which nutritive plasma penetrates the matrix of cartilage to he cells. Budge endeavoured to demonstrate the existence of canaliculi ng coloured injecting fluid into the substance of cartilage, but the result xperiment was not conclusive. It has also been attempted to show them o-called natural method of injection, that is by allowing indigo-carmine has an intensely blue colour) to mix with the circulating blood of animals, fter a time are killed and the cartilages examined. Proceeding in this way, was unable to see any blue channels in the cartilage matrix, while on the other hand, obtained results from which he was led to infer the e of minute cleft-like spaces throughout the matrix connected by fine g canaliculi on the one hand with the lymphatics in the perichondrium. the other hand with the cell-spaces of the cartilage.

is the structure of hyaline cartilage in general, but it is more or odified in different situations.

In *articular cartilage*, the matrix in a thin section appears dim, like ground glass, having sometimes an almost granular aspect. The cells and cell-groups are smaller and more dispersed, as a rule, than in rib-cartilage. As is the case also with the cartilage of the ribs, the groups are flattened at and near to the surface, and lie parallel with it (fig. 81, *a*);

Fig. 81.

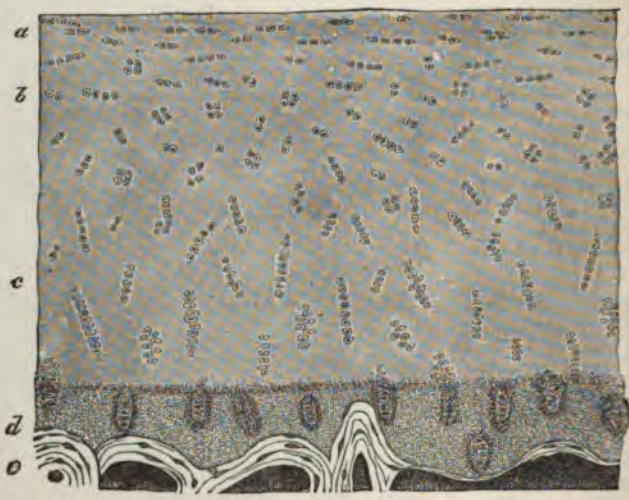


Fig. 81.—VERTICAL SECTION OF ARTICULAR CARTILAGE COVERING THE LOWER END OF THE TIBIA (HUMAN). MAGNIFIED ABOUT 30 DIAMETERS. (E. A. S.)

a, cells and cell-groups flattened conformably with the surface; *b*, cell-groups irregularly arranged; *c*, cell-groups disposed perpendicularly to the surface; *d*, layer of calcified cartilage; *e*, bone.

deeper and nearer the bone, on the other hand, they are narrow and oblong, like short irregular strings of beads, and are mostly directed vertically (fig. 81, *c*). It is well known that articular cartilages readily break in a direction perpendicular to their surface, and the surface of the fracture appears to the naked eye to be striated in the same direction, as if they had a columnar structure; this may be due to the vertical arrangement of the rows of cells, or to the substance of the matrix being disposed in a fibrous or columnar manner (Leidy). It was formerly held that the free surface of articular cartilage is covered with epithelium, but no such covering really exists. It is easy, no doubt, to peel off a thin film from the surface of the cartilage of the head of the humerus or femur; but this superficial layer is really part of the cartilage, and its broad patches of cells with the intermediate matrix are not to be mistaken (fig. 82).

Near the margin of the articular cartilages connective tissue is prolonged a certain way into them from the synovial membrane, and the cartilage-cells acquire processes and present transitions to the connective-tissue corpuscles of that membrane (fig. 83).

The matrix of articular cartilage rarely, or perhaps never, becomes converted into fibro-cartilage, nor is it prone to ossify like rib-cartilage.

that a deposit of calcareous granules may occur in the deeper parts of the articular cartilage near the bone, the deposit first showing itself

Fig. 82.

Fig. 82.—A THIN LAYER PEELED OFF FROM THE SURFACE OF THE CARTILAGE OF THE HEAD OF THE HUMERUS, SHOWING FLATTENED GROUPS OF CELLS (Sharpey).

The shrunken cell-bodies are distinctly seen, but the limits of the capsular cavities where they adjoin one another are but faintly indicated. Ranfiel 400 diameters.

around the groups of cartilage cells (fig. 81, *d*). This change may also happen at the symphyses. When the earthy matter is extracted by means of an acid, the tissue which remains has all the characters of cartilage.

In the *costal cartilages*, the cells, which are of considerable size, are also collected in groups, larger for the most part than those found in articular cartilage. Near the exterior of the cartilage they are flattened, and lie parallel with the surface. As to those situated more inwardly, we can sometimes observe, in a transverse slice, that they form oblong groups disposed in lines radiating to the circumference; but this arrangement is not constant, and they often appear quite irregular. The cells, with the exception of those lying upon the surface, frequently contain drops of oil, the nucleus being often altogether concealed by the fat. The matrix is clear, except where fibres have been developed in it, in which parts it is opaque and yellowish. Such fibrous patches

Fig. 83.

Fig. 83.—BORDER OF ARTICULAR CARTILAGE SHOWING TRANSITION OF CARTILAGE CELLS INTO CONNECTIVE-TISSUE CORPUSCLES. FROM HEAD OF METATARSAL BONE, HUMAN. ABOUT 340 DIAMETERS (R. A. S.).

a, ordinary cartilage cells; *b*, *b*, with branching processes.

are very frequent; the fibres are fine, straight, and parallel, appearing transparent when few together; they are not swollen by acetic acid. It is not uncommon to find the rib-cartilages extensively ossified.

The description given of the microscopic characters of the costal cartilages will apply with little variation to the ensiform cartilage of the sternum, to the cartilages of the larynx and windpipe, except the epiglottis and cornicula laryngis, and to the cartilages of the nose. With the exception of the last, these resemble the rib-cartilages also in their tendency to ossify.

The characters of the temporary cartilages, which are hyaline, will be noticed in the account of the formation of bone.

ELASTIC OR YELLOW CARTILAGE.

The epiglottis and cornicula of the larynx, the cartilages of the ear and of the Eustachian tube, differ so much from the foregoing, both in intimate structure and outward characters, that they have been included in a class apart, under the name of the "elastic," "yellow," or "spongy" cartilages. These are opaque and somewhat yellow, are more flexible and tough than the ordinary cartilages, and have little tendency to ossify. They are made up of cells and a matrix, but the latter is everywhere pervaded with fibres (fig. 84), except in a small area or narrow zone (shaded in the figure) left round each of the cells. The fibres resist the action of acetic acid; they are in many parts short, fine, and confusedly intersecting each other in all directions, like the filaments in a piece of felt; in such parts the matrix has a rough indistinctly granular look, but sometimes this appearance is due to the fact that the elastic fibres are incompletely developed, the granules which are to form them having not yet run together into fibres (fig. 85, *b*). Sometimes the fibres are longer (fig. 85, *c*) but they still intercommunicate at short distances.

Fig. 84. Fig. 85.

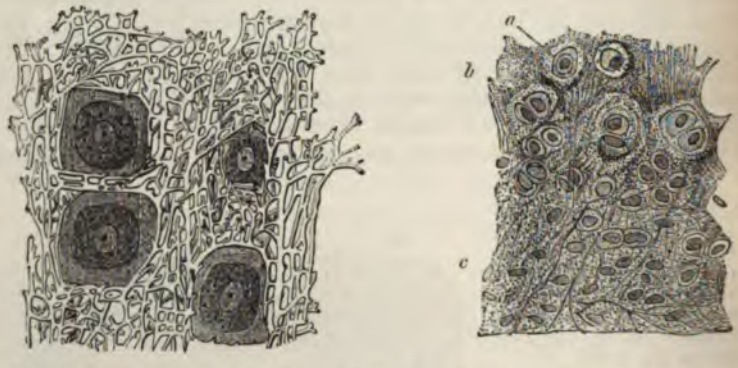


Fig. 84.—Section of the elastic cartilage of the ear. Highly magnified (Hertwig).

Fig. 85.—Section of part of the cartilage of the epiglottis (Ranvier).

a, cartilage cell in clear area; *b*, granular-looking matrix near the middle of the cartilage, the granular appearance being due partly to the fine reticulum of elastic fibres, partly to the presence of granules of elastic substance in the matrix; *c*, clearer matrix with longer fibres.

In large animals such as the ox, where the fibres of ordinary elastic tissue attain a considerable size, those of elastic cartilage are also very large with comparatively wide meshes, occupied of course by the hyaline ground-substance.

WHITE FIBRO-CARTILAGE.

This is a substance consisting of a mixture of the fibrous and cartilaginous tissues, and so far partaking of the qualities of both. Like hyaline cartilage, it possesses firmness and elasticity, but these properties are united with a much greater degree of flexibility and toughness. It

resents itself under various forms, which may be enumerated under the following heads :—

1. *Interarticular* fibro-cartilages. These are interposed between the moving surfaces of bones, or rather of articular cartilages, in several of the joints. They serve to maintain the apposition of the opposed surfaces in their various motions, to give ease to the gliding movement, and to moderate the effects of great pressure. In the joint of the lower jaw and in that of the clavicle they have the form of round or oval plates, growing thinner towards the centre; in the knee-joint they are curved in form of a sickle, and thinned away towards their concave free edge. In all cases their surfaces are free; while they are fixed by synovial or fibrous membrane at their circumference or extremities. The synovial membrane of the joint is prolonged for a short distance upon these fibro-cartilages, from their attached margin.

2. The articular cavities of bones are sometimes deepened and extended by means of a rim or border of fibro-cartilage. Good examples of these *circumferential* or *marginal* fibro-cartilages are seen in the shoulder and hip-joints, attached round the lip of the articular sockets.

3. *Connecting* fibro-cartilages are such as pass between the adjacent surfaces of bones in joints which do not admit of gliding motion, as at the symphysis of the pubis and between the bodies of the vertebræ. They have the general form of disks, and between the vertebræ are composed of concentric rings of fibrous tissue with cartilage-cells and matrix interposed; the fibrous tissue predominating at the circumference, the cartilaginous tissue increasing towards the centre. The bony surfaces which they connect are usually encrusted with true cartilage.

4. The bony grooves in which tendons of muscles glide are lined with a thin layer of fibro-cartilage. Small nodules of this tissue (*sesamoid fibro-cartilages*) may also be developed in the substance of tendons, of which there is an example in the tendon of the peroneus longus, and also in that of the tibialis posticus, where it passes beneath the head of the astragalus. Lastly, we have an example of the occasional connection of fibro-cartilage with muscle, in the attachment given by it to muscular fibres at the base of the ventricles of the heart.

Fig. 86.

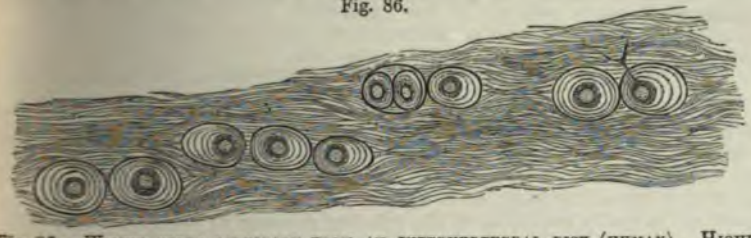


Fig. 86.—White fibro-cartilage from an intervertebral disk (human). Highly magnified (E. A. S.).

The concentric lines around the cells indicate the limits of deposit of successive capsules. One of the cells has a forked process which extends beyond the hyaline area surrounding the cell, amongst the fibres of the general matrix.

Fibro-cartilage appears under the microscope to be made up of wavy fibres, like those of ordinary ligament, with cartilage-cells occupying the place, and often simulating the arrangement, of the tendon-cells. As in elastic fibro-cartilage, the cells are immediately surrounded by a part of the matrix which is free from fibres (fig. 86). As a general rule they resemble the cells of ordinary cartilage, having a rounded shape, although somewhat flattened where the bundles of fibres are closely packed.

In the intervertebral fibro-cartilages, many of the cartilage cells are provided with long and ramified processes that extend far beyond the body of the cell.

The proportion which the fibrous bundles bear to the true cartilage, differs much in different examples of this tissue. In general the fibrous tissue very greatly predominates, and in some cases, as in the inter-articular laminæ of the knee-joint, it constitutes almost the entire structure, but cartilaginous tissue with characteristic cells predominates near the surfaces. In the intervertebral disks the cartilage-corpuscles are, as already stated, more abundant towards the central pulp than near the periphery, but the pulp itself does not in most instances contain cartilage-cells, but a reticulated cell-structure embedded in soft matrix, and probably derived from the cells of the chorda dorsalis of the embryo.

In the healthy state, no blood-vessels penetrate the articular cartilages. Whatever nutrient fluid they require seems to be derived from the vessels of adjoining textures, especially the bone, and to be conveyed through the tissue by imbibition. Towards the circumference of the cartilage, however, underneath the synovial membrane, the synovial vessels form a narrow vascular border round it, which has been named the *circulus articuli vasculosus*.

When the tissue exists in thicker masses, as in the cartilages of the ribs, canals are here and there excavated in its substance, along which vessels are conducted for the nourishment of the parts too distant to receive it from the vessels of the perichondrium. But these canals are few and wide apart, and the vessels do not pass beyond them to ramify in the intermediate mass, which is accordingly quite extravascular.

No nerves have been traced into any of the cartilages, and they are known to be destitute of sensibility.

The matrix of cartilage is chiefly composed of a substance which is converted after long boiling into chondrin. White fibro-cartilage yields gelatine in addition. A certain amount of gelatine is said (by Kühne) also to be yielded by hyaline cartilage.

DEVELOPMENT OF CARTILAGE.

The parts of the embryo which are to become cartilages are made up at first of the common mesodermic cells from which the connective tissues generally originate. After a time the cell-contents become clearer, the nucleus more visible, and the cells, mostly of polygonal outline, appear surrounded by clear lines of pellucid substance, forming as it were a network of bright meshes inclosing them, but in reality consisting of the cohering capsules of the contiguous cells, and constituting all that exists of the matrix at this time.* Glycogen appears at an early period in the protoplasm of cartilage-cells. Rouget found it in the sheep's embryo of two months, both in ossifying cartilage and in the cartilages of the trachea.

The subsequent changes consist in enlargement and multiplication of the cells and development of the intermediate matrix from a substance which is formed around and between them. The process appears to be as follows (fig. 87) :—The cartilage cells first divide, a species of capsule being formed round each of the young cells (B), whilst the old one inclosing them becomes blended with the intercellular matrix, and is no longer traceable (C). The new cells, in turn, divide in the same way, so as to make a group of four, each of which is surrounded by its own capsule (D), whilst the capsules of the first descent (secondary) blend with the matrix (E) like their predecessor.

The four cells may each form a succession of capsules and thus become more

* Cartilages, which retain this condition throughout life, have been termed "parenchymatous." An example of this is found in the cartilage of the mouse's ear.

separated from one another, or they may divide again and form a group of eight or more. It is by reason of the cells remaining in contiguity with one another after the division is complete that the groups of corpuscles which are so characteristic of cartilage are produced.

It is doubtful how the capsule is produced; whether excreted by the cell which it afterwards incloses, as held by Kölliker; or formed by conversion of a superficial layer of the protoplasm of the cell-body, as was taught by Max Schultze; or a primarily independent deposit around the cells. However this may be, there is at first no matrix but what is made up of the simple capsules.

Fig. 87.

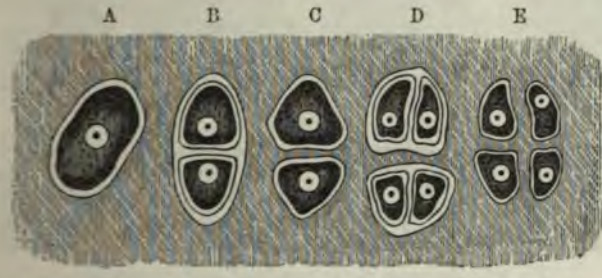


Fig. 87.—IDEAL PLAN OF THE MULTIPLICATION OF CELLS OF CARTILAGE (Sharpey).

A, cell in its capsule; B, divided into two, each with a capsule; C, primary capsule disappeared, secondary capsules coherent with matrix; D, tertiary division; E, secondary capsules disappeared, tertiary coherent with matrix.

In further growth there is a difference, according as the cells do or do not undergo frequent division. In the latter case a cell becomes surrounded by many concentric capsules formed in succession; that is, the first capsule is expanded, and the others formed each within its expanding predecessor, so that the cartilage comes to consist of scattered cells, each with a concentric system of capsules, which by means of re-agents may be rendered visible in the neighbourhood of the cells, but further off are inseparably blended into a uniform substance. When, on the other hand, the cells have a tendency to frequent subdivision, the new capsules are produced by the new cells, and are included in and finally blend with those which had belonged to the previous cells, as shown by fig. 87.

The matrix, although thus formed of the capsules, usually becomes to all appearance homogeneous; but in sections of cartilage that have been exposed to acids and other re-agents, the contour lines of the capsules round cells and cell-groups may be more or less distinctly brought into view.

The mode in which the division of the cartilage-cell takes place has been carefully studied by Schleicher, and the stages of the process followed in the living tissue (fig. 88). The nuclear membrane first of all disappears, or is converted into filaments of nucleoplasm. These become lost amongst the other filaments which result from the conversion of the nucleoli and other more solid contents of the nucleus. The filaments are at first short and irregular (*a*), and soon take on a stellate arrangement (*b*). After a time they become grouped in a parallel manner in the centre of the nucleus (*c-d*), this phase corresponding with the equatorial stage of division described by Flemming (vide ante, p. 13). The parallel fibres soon divide into two groups, which pass towards the poles of the nucleus. Sometimes the gap between the groups is bridged across for awhile by fine filaments. The two groups of fibres next undergo a gradual process of conversion into the daughter-nuclei (*e-h*).

It will be seen, from the above account, that the division of the *nucleus* of the cartilage cell resembles on the whole that which has been observed in other cells, although all the details of the process have not been distinctly followed. The mode

of division of the *cell-substance* is, however, different, for in place of a constriction appearing and gradually separating the protoplasm into two halves from without in, a partition is formed (*e*), in the middle of the now elongated cell, being produced according to Schleicher, by the accumulation in this situation of some of the filaments, which, as before mentioned (p. 78), occur in the cell-protoplasm. However this may be, the septum, as soon as it is broad enough, is seen in reality to consist of two layers, which are continuous with the capsules of the two daughter cells (*f*).

Fig. 88.

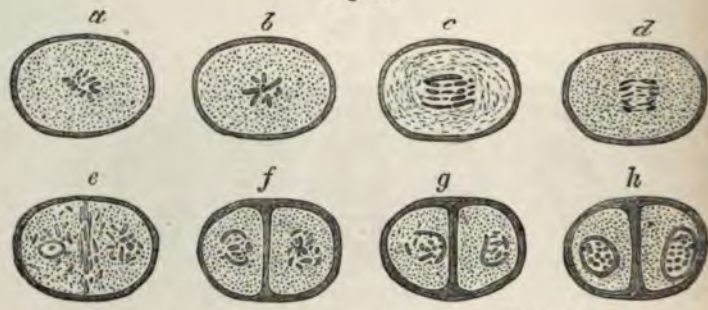


Fig. 88.—Division of a cartilage cell (Schleicher).

a-h, stages of division of a cell, as seen in the living cartilage of the salamander (the connection of the nucleoplasmic filaments could not be made out in the fresh condition). *a*, *b*, stellate phase; *c*, equatorial phase; *d*, commencing separation of the nucleo-plasmic filaments; the further stages of separation are not represented; *e*, filaments fully separated into two groups, and a septum beginning to be formed between them; *f*, septum completed, seen to be double and continuous with capsules of daughter cells; *g*, *h*, further stages in the formation of the daughter nuclei.

In the case of elastic cartilage the matrix is at first hyaline, and the elastic fibres are subsequently produced in it. They appear in the form of fine granules in those parts of the matrix that are in immediate contiguity with the cartilage cells. In the cartilage of the external ear this change occurs about the fifth month of intra-uterine life, commencing in the more central parts, and gradually extending outwards towards the perichondrium.

The mode of development of white fibro-cartilage has not been definitely ascertained.

Nutrition and Regeneration.—The vital changes which occur in cartilage take place very slowly. Its mode of nutrition has been already referred to; it is subject to absorption, and when a portion is absorbed in disease or removed by the knife, it is either not regenerated at all or but very slowly. A wound in cartilage is usually at first healed by connective tissue, which becomes gradually transformed into or gives place to hyaline cartilage. The reappearance of the latter seems, however, to depend upon the presence of the perichondrium, this membrane fulfilling, although perhaps not to so marked an extent, the same functions in the regeneration of cartilage as does the periosteum in the regeneration of bone. Schwalbe found that the cartilage of the rabbit's ear grew only by apposition at its margins and surfaces, and not interstitially; but it is certain that the temporary cartilages grow in the manner last mentioned.

When a cartilage is fractured, as sometimes happens with the rib-cartilages, the broken surfaces become connected, especially at their circumference, by fibrous or dense areolar tissue, and often by a bony clasp.

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BONE OR OSSEOUS TISSUE.

The bones are the principal organs of support, and the passive instruments of locomotion. Connected together in the skeleton, they form a framework of hard material, which affords attachment to the soft parts, maintains them in their due position, and shelters such as are of delicate structure, giving stability to the whole fabric, and preserving its shape; and the different pieces of the skeleton, being joined moveably together, serve also as levers for executing the movements of the body.

While substantially consisting of hard matter, bones in the living body are covered with periosteum and filled with marrow; they are also pervaded by blood-vessels for their nutrition.

Bone has a white colour, with a pink and slightly bluish tint in the living body. Its hardness is well known, but it also possesses a certain degree of toughness and elasticity; the last property is peculiarly well marked in the ribs. Its specific gravity is from 1.87 to 1.97.

Chemical Composition.—Bone consists of an earthy and an animal part, intimately combined together; the former gives hardness and rigidity, the latter tenacity, to the osseous tissue.

The earthy part may be obtained separate by calcination. When bones are burned in an open fire, they first become quite black, like a piece of burnt wood, from the charring of their animal matter; but if the fire be continued with free access of air, this matter is entirely consumed, and they are reduced to a white, brittle, chalk-like substance, still preserving their original shape, but with the loss of about a third of their weight. The earthy constituent, therefore, amounts to about two-thirds of the weight of the bone. It consists principally of phosphate of lime, with about a fifth part of carbonate of lime, and much smaller proportions of fluoride of calcium, chloride of sodium, and magnesian salts.

The animal constituent may be freed from the earthy, by steeping a

bone in diluted hydrochloric acid. By this process the salts of lime are dissolved out, and a tough flexible substance remains, which, like the earthy part, retains the perfect figure of the original bone in its minutest details; so that the two are evidently combined in the most intimate manner. The animal part is often named the cartilage of bone, but improperly, for it differs entirely from cartilage in structure, as well as in physical properties and chemical nature. It is much softer and much more flexible, and, by boiling, it is almost wholly resolved into gelatin. It may accordingly be extracted from bones, in form of a jelly, by boiling them for a considerable time, especially under high pressure.

In the compact substance of a femur that had been long buried, Aeby found only 16·5 per cent. of animal matter.

The fluoride of calcium is found in larger quantity in fossil than in recent bones.

MINUTE STRUCTURE OF BONE.

On sawing up a bone, it will be seen that it is in some parts dense and close in texture, appearing like ivory; in others open and reticular: and anatomists accordingly distinguish two forms of osseous tissue, viz., the *compact*, and the *spongy* or *cancellated*. On closer examination, however, especially with the aid of a magnifying glass, it will be found that the bony matter is everywhere porous in a greater or less degree, and that the difference between the two varieties of tissue depends on the different amount of solid matter compared with the size and number of the open spaces in each; the cavities being very small in the compact parts of the bone, with much dense matter between them; whilst in the cancellated texture the spaces are large, and the intervening bony partitions thin and slender. There is, accordingly, no abrupt limit between the two,—they pass into one another by degrees, the cavities of the compact tissue widening out, and the reticulations of the cancellated becoming closer as they approach the parts where the transition between the two takes place.

In all bones, the part next the surface consists of compact substance, which forms an outer shell or crust, whilst the spongy texture is contained within. In a long bone, the large round ends are made up of spongy tissue, with only a thin coating of compact substance; in the hollow shaft, on the other hand, the spongy texture is scanty, and the sides are chiefly formed of compact bone, which increases in thickness from the extremities towards the middle, at which point the girth of the bone is least, and the strain on it greatest. In tabular bones, such as those of the skull, the compact tissue forms two plates, or tables, as they are called, inclosing between them the spongy texture, which in such bones is usually named *diploë*. The short bones, like the ends of the long, are spongy throughout, save at their surface, where there is a thin crust of compact substance. In the complex or mixed bones, such as the vertebræ, the two substances have the same general relation to each other; but the relative amount of each in different parts, as well as their special arrangement in particular instances, is very various.

On close inspection the cancellated texture of bone is seen to be formed of slender bars or spicula and thin lamellæ, which meet together and join in a reticular manner, producing an open structure which has been compared to lattice-work (*cancelli*), and hence the name usually

applied to it. In this way considerable strength is attained without undue weight, and it may usually be observed that the strongest laminæ run through the structure in those directions in which the bone has naturally to sustain the greatest pressure. The open spaces or areolæ of the bony network communicate freely together; in the fresh state they contain marrow or blood-vessels, and give support to these soft parts.

Fig. 89.

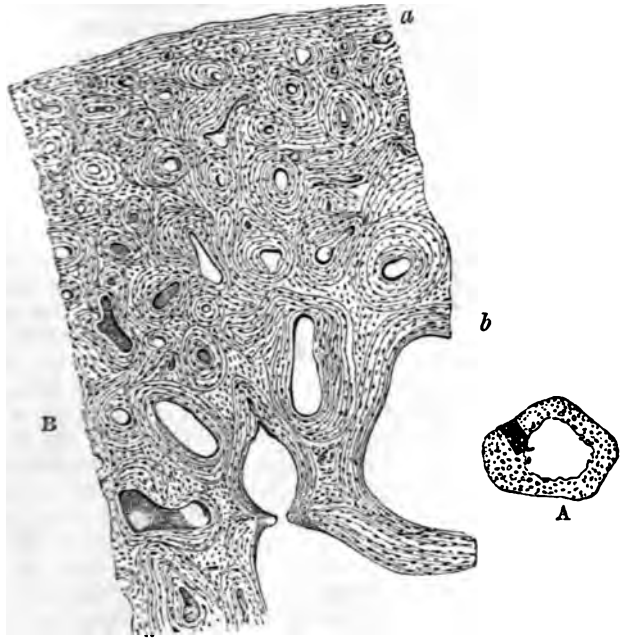


Fig. 89.—A, TRANSVERSE SECTION OF A BONE (ULNA) DEPRIVED OF ITS EARTH BY ACID (Sharpey).

The openings of the Haversian canals are seen. Natural size. A small portion is shaded to indicate the part magnified in Fig. B.

B, PART OF THE SECTION A, MAGNIFIED 20 DIAMETERS.

The lines indicating the concentric lamellæ are seen, and among them the lacunæ appear as little dark specks.

Haversian canals.—The compact tissue is also full of holes; these, which are very small, are best seen by breaking across the shaft of a long bone near its middle and examining it with a common magnifying glass. Numerous little round apertures (fig. 89 A) may then be seen on the broken surface, which are the openings of short longitudinal passages running in the compact substance, and named the *Haversian canals*, after Clopton Havers, an English physician and writer of the seventeenth century, who more especially called attention to them. Blood-vessels run in these canals, and the widest of them also contain marrow. They are from $\frac{1}{1000}$th to $\frac{1}{500}$th of an inch in diameter: there are some no more than $\frac{1}{1000}$th, but these are rare; the medium size is

about $\frac{1}{500}$th. The widest are met with nearest the medullary cavity, and the narrower towards the circumference of the bone. They are quite short, as may be seen in a longitudinal section, oblique communications connecting them freely both longitudinally and laterally. Those which are next the circumference of the bone, open by minute pores on its external surface, and the innermost ones open widely into the medullary cavity; so that these short channels collectively form a sort of irregular network of tubes running through the compact tissue, in which the vessels of that tissue are lodged, and through the medium of which these vessels communicate together, not only along the length of the bone, but from its surface to the interior through the thickness of the shaft. The canals of the compact tissue in the other classes of bones have the same general characters, and for the most part run parallel to the surface.

Lamellæ.—On viewing a thin transverse section of a long bone with a microscope of moderate power, especially after the earthy part has been removed by acid (fig. 89 B; fig. 95), the opening of each Haversian canal appears to be surrounded by a series of concentric rings. This appearance is occasioned by the transverse sections of concentric *lamellæ* which surround the canals. The rings are not all complete, for here and there one may be seen ending between two others. In some of the sets, the rings are nearly circular, in others oval,—differences which seem mostly to depend on the direction in which the canal happens to be cut: the aperture too, may be in the centre, or more or less to one side, and in the latter case the rings are usually narrower and closer together on the side towards which the aperture deviates. Again, some of the apertures are much lengthened or angular in shape, and the lamellæ surrounding them have a corresponding disposition. Besides the lamellæ surrounding the Haversian canals, there are others disposed conformably with the circumference of the bone (fig. 89 B, *a*), most of these are near the surface, but others run between the Haversian sets, by which they are interrupted in many places (fig. 95). Lastly, in various parts of the section, lines are seen which indicate lamellæ, differing in direction from both of the above-mentioned orders.

The appearance in a longitudinal section of the bone is in harmony with the account above given: the sections of the lamellæ are seen as straight and parallel lines, running in the longitudinal direction of the bone, except when the section happens to have passed directly or slantingly across a canal: for wherever this occurs there is seen, as in a transverse section, a series of rings, generally oval and much lengthened on account of the obliquity of the section.

The cancellated texture has essentially the same lamellar structure. The slender bony walls of its little cavities or areolæ are made up of superimposed lamellæ, like those of the Haversian canals, only they have fewer lamellæ in proportion to the width of the cavities which they surround; and, indeed, the relative amount of solid matter and open space constitutes, as already said, the only difference between the two forms of bony tissue: the intimate structure of the solid substance and the manner of its disposition round the cavities being essentially the same in both.

Lacunæ and canaliculi.—All over the section numerous little dark specks are seen among the lamellæ. These were named the "osseous corpuscles;" but as it is now known that they are in reality minute

sting in the bony substance, the name of *lacunæ* has since ittingly applied to them. To see the lacunæ properly, how- ıs of unsoftened bones must be prepared and ground very magnifying power of from 200 to 300 must be employed. ion, viewed with transmitted light, has the appearance repre- r. 90. The openings of the Haversian canals are seen with ling lamellæ, and among these the lacunæ, which are mostly corresponding order, appear as black or dark brown and ne oblong spots, with fine dark lines extending from them r them to look not unlike little black insects. The dark is due to the fact that the little cavities have become filled the dry bone, and when the same section is seen against a d, with the light falling on it (as we usually view an opaque little bodies and lines appear quite white, like figures drawn on a slate, and the intermediate substance, being transparent, dark.

Fig. 90.

ANSVERSE SECTION OF COMPACT TISSUE (OF HUMERUS) MAGNIFIED ABOUT 150 DIAMETERS (Sharpey).

Haversian canals are seen, with their concentric rings; also the lacunæ, aliculi extending from them across the direction of the lamellæ. The rtures had become filled with débris in grinding down the section, and ar black in the figure, which represents the object as viewed with trans-

næ, as already stated, are minute recesses in the bone, and tending from them are fine pores or tubes named *canaliculi*, from their cavity. The lacunæ present some variety of in such a section as that represented they for the most part gularly fusiform, and lie nearly in the same direction as the ween which they are situated; or, to speak more correctly, ttened and extended conformably with the lamellæ; for one is cut longitudinally, their sections still appear fusiform ill more lengthened out in the direction of the lamellæ.

The canaliculi, on the other hand, pass across the lamellæ, and they communicate with those proceeding from the next range of lacunæ, so as to connect the little cavities with each other; and thus since the canaliculi of the most central range open into the Haversian canal, a system of continuous passages is established by these minute tubes and their lacunæ, along which fluids may be conducted from the Haversian canal through its series of surrounding lamellæ; indeed, it seems probable that a chief purpose of these minute passages is to allow nutrient matter to be conveyed from the vascular Haversian canals through the mass of hard bone which lies around and between them. In like manner the canaliculi open into the great medullary canal, and into the cavities of the cancellated texture; for in the thin bony parietes of these cavities lacunæ are also contained; they exist, indeed, in all parts of the bony tissue. The canaliculi which radiate outwards from the lacunæ near the periphery of the Haversian systems do not as a rule communicate with those of the neighbouring Haversian system, but bend round and are joined to one another.

Cells of bone.—As first shown by Virchow, each lacuna is occupied by a flattened nucleated cell, which sends branches along the canaliculi; and later observers (Rouget, Neumann,) have been able to detach the

Fig. 91.

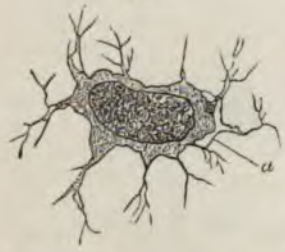


Fig. 91. A BONE-CELL ISOLATED AND HIGHLY MAGNIFIED (after Joseph).

a, proper wall of the lacuna, shown at a part where the corpuscle has shrunk away from it.

proper wall of the lacuna and its appertaining canaliculi after decalcification, and to obtain it separate with its included corpuscle. It can scarcely be doubted that the protoplasm of the nucleated corpuscle takes an important share in the nutritive process in bone, and very probably serves both to modify the nutritive fluid supplied from the blood and to further its distribution through the lacunar and canalicular system of the bony tissue. Virchow showed that the corpuscles of bone are homologous with those of connective tissue: to this it may be added that the enclosing lacunæ and canaliculi are to be looked upon as corresponding to the cell-spaces of that tissue.

Apertures and decussating fibres of the lamellæ.—With a little pains, thin films may be peeled off in a longitudinal direction from a piece of bone that has been softened in acid. These for the most part consist of several lamellæ, as may be seen at the edge, where the different layers are usually torn unequally, and some extend farther than others. Examined in this way, under the microscope, the lamellæ are seen to be perforated with fine apertures placed at very short distances apart. These apertures were described by Deutsch;* they appear to be the transverse sections of the canaliculi already described, and their relative distance and position accord sufficiently with this explanation. According to this view, therefore, the canaliculi might (in a certain sense) be conceived to result from the apposition of a series of perforated plates, the apertures

* De Penitiori Ossium Structurâ. Wratisl. 1834, p. 17, Fig. 6.

plate corresponding to those of the plates contiguous with it ; or ght be compared to holes bored to some depth in a straight ked direction through the leaves of a book, in which case it is at the perforations of the adjoining leaves would correspond ; it nderstood, however, that the passages thus formed are most likely l by proper parietes. The apertures now referred to must be dis- ed from larger holes seen in some lamellæ, which give passage to orating fibres to be mentioned further on.

he lamellæ have a further structure. To see this, the thinnest a detached shred or film must be examined, as shown in figs. 92 ; it will then appear plainly that they are largely made up of ent fibres, decussating with each other in the form of an gly fine network. In the Haversian systems these decussating oss one another in different lamellæ at right angles (v. Ebner), ost other situations at more or less acute angles, and they are ere and there by obliquely passing fibres, so that they cannot l out from one another ; but at the torn edge of the lamella y often be seen separate for a little way, standing out like the of a fringe. Most generally they are straight, as represented in

Fig. 92.

-THIN LAYER PEELED OFF FROM A SOFTENED AS IT APPEARS UNDER A MAGNIFYING POWER OF AMETERS (Sharpey).

ure, which is intended to represent the reticular of a lamella, gives a better idea of the object rather farther off than usual from the eye.

but they are not always so, for in some ey assume a curvilinear direction (fig. 94). r hydrochloric acid causes these fibres to and become indistinct, like the white f connective tissue; care must therefore n in their examination that the remains decalcifying acid be removed from the y maceration in water or in solutions of salts. Moreover, the fibro-reticular e is not equally distinct in all parts; for in some places it is idedly marked, as if the fibrillation were incompletely developed.

cussating fibres which constitute the lamellæ were discovered by Sharpey, r constant presence was taught by him for a long time before they were by other histologists. It has lately been shown by v. Ebner that the ng fibres of Sharpey are in reality themselves composed of exquisitely ls, so that they correspond with bundles of white connective tissue fibres an with single fibres. Like the connective tissue fibrils these of the bone bly refracting, and they are said not to be calcified, the deposit of s matter being confined to the matrix in which they are embedded. They be united into the lamellæ by a matrix or ground-substance, and accord- Ebner take different directions in successive lamellæ, so as to produce ar or a striated appearance according as they happen to be cut trans- r longitudinally (fig. 93).

n sections of bone, the concentric lines or rather bands which represent dges of the lamellæ show the section of the decussating fibres as round ar dots, themselves punctated, which lie embedded in the homogeneous ubstance (fig. 93, *b*). The lamellæ are separated from one another by næ which lie between them, where these are absent they are joined

together by the ground-substance ; they may also be united by occasional bundles of fibres passing obliquely from one lamella to the other.

Fig. 93.

Fig. 93.—Small part of a longitudinal section of decalcified tibia. Highly magnified (after v. Ebner).

a, series of six lamellæ which are cut for the most part in the direction of the fibrils, so that they appear longitudinally striated ; *b*, *b*, lamellæ, the fibrils of which are cut across ; the arrangement of the fibrils into bundles is indicated. Two or three lacunæ are seen lying between the lamellæ, their canaliculi piercing the lamellæ.

Perforating fibres.—It was further shown by Sharpey that in many instances the lamellæ are perforated by fibres, which pass through them in a perpendicular, or oblique direction, and, as it were, bolt them together. These perforating fibres may be seen, with the aid of the microscope, in a thin transverse slice of a decalcified cylindrical or cranial bone, on pulling asunder the sections of the lamellæ (as in fig. 96). In this way some lamellæ will generally be observed with fibrous processes attached to them (fig. 96, *b*) of various lengths, and usually tapering and pointed at their free extremities, but sometimes truncated—probably from having been divided by the knife. These fibres have obviously been drawn out from the adjacent lamellæ, through several of which they must have penetrated. Sometimes, indeed, indications of perforations may be recognised in the part of the section of bone from which the

Fig. 94.

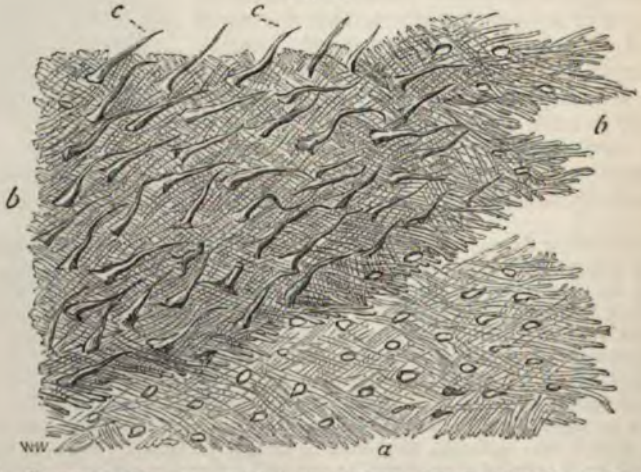


Fig. 94.—Lamellæ torn off from a decalcified human parietal bone at some depth from the surface (Sharpey).

a, lamellæ, showing decussating fibres ; *b*, *b*, thicker part, where several lamellæ are superposed ; *c*, *c*, perforating fibres. Apertures through which perforating fibres had passed, are seen especially in the lower part, *a*, *a*, of the figure. Magnitude as seen under a power of 200, but not drawn to a scale (from a drawing by Allen Thomson).

fibres have been pulled out (fig. 96, *c*). The processes in question are thus, so to speak, viewed in profile; but they may frequently also be seen on the flat surface of detached lamellæ (fig. 94), projecting like nails driven perpendicularly.

The perforating fibres are, like the decussating fibres, for the most part bundles of fibrils which agree in character with those of the white fibrous tissue; but some, as shown by H. Müller, are of the nature of elastic tissue (fig. 95, *e*). In some parts they escape calcification,

Fig. 95.

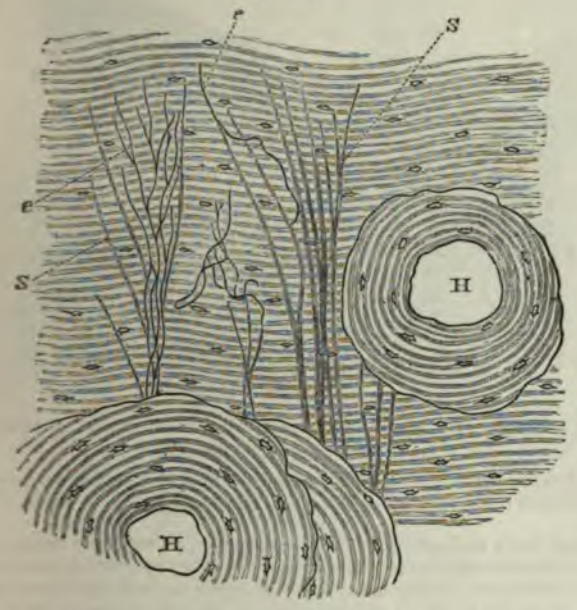


Fig. 95.—TRANSVERSE SECTION OF DECALCIFIED HUMAN TIBIA, FROM NEAR THE SURFACE OF THE SHAFT (E. A. S.).

H, H, Haversian canals, with their systems of concentric lamellæ; in all the rest of the figure the lamellæ are circumferential.

S, ordinary perforating fibres of Sharpey; *e*, *e*, elastic perforating fibres. Drawn under a power of about 150 diameters.

and thus, as they shrink in drying, leave tubes or channels in the dry bone, generally leading from the surface inwardly; but these uncalcified fibres are by no means frequent. The perforating fibres are often connected with the periosteum, as is the case with most of those which penetrate the external table of the cranial bones; but in cross sections of cylindrical bones they often appear to spring with their broad ends from the deeper lamellæ (with the fibres of which they may be directly continuous), and especially from those near the circumference of a Haversian system, and taper outwards into fine points, which do not reach the periosteum (fig. 95); although without doubt they must, like the bony layers in which they occur, have been formed by subperiosteal ossification. They are rarely if ever found in the concentric

systems of Haversian lamellæ. Perforating fibres exist abundantly in the *crusta petrosa* of the teeth (Sharpey).

Where tendons or ligaments are inserted into bone, the fibre-bundles of the tendon are continued into the bone as perforating fibres, so that the attachment of tendon to bone is thus rendered very intimate. Some of the bundles of white fibres of the periosteum may also, as above mentioned, pass into the bone as perforating fibres, and the same is the case with the elastic fibres.

Fig. 96.

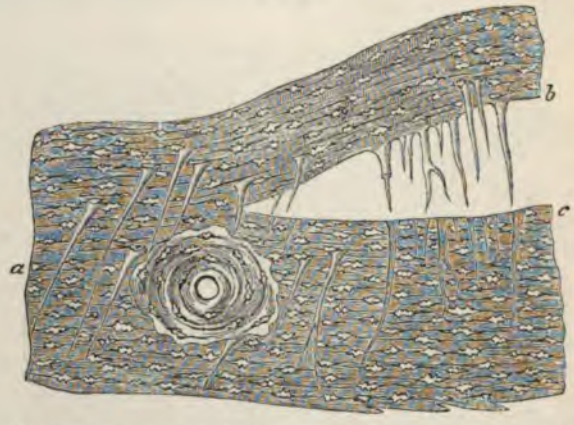


Fig. 96.—MAGNIFIED VIEW OF A PERPENDICULAR SECTION THROUGH THE EXTERNAL TABLE OF A HUMAN PARIETAL BONE, DECALCIFIED (H. Müller).

At *a*, perforating fibres in their natural situation ; at *b*, others drawn out by separation of the lamellæ ; at *c*, the holes or sockets out of which they have been drawn (H. Müller).

The animal basis of bone is made up essentially, as we have seen, of lamellæ composed of fine decussating or reticular fibril-bundles embedded in a ground-substance ; but interposed among these lamellæ, layers are here and there met with of a different character, having a granular aspect, with the lacunæ very conspicuous and regularly arranged, and sometimes appearing as if surrounded by faintly defined areolæ. These generally incomplete layers are often bounded by a scalloped border, as if made up of confluent round or oval bodies ; this is indicated also by the occasional occurrence of oval or flattened spheroidal bodies singly or in small groups near the border of the layers, each with a lacuna in the centre. In some parts the granular substance is obscurely fibrous, and transitions may be observed to the well-marked reticular laminæ. The layers described appear principally to occur near the surface of the compact tissue, and at the circumference of many of the systems of concentric Haversian lamellæ.

Irregular layers of rounded bodies, apparently solid and without central cavity, are also sometimes seen, and are well represented in figure 97. These layers are met with chiefly near the surface of the shaft of long bones, lying among the circumferential laminæ, and apparently forming only part of a circuit. They can occasionally be recognised in a transverse section as short curvilinear bands of peculiar aspect, broader in the middle and thinning away at the ends, appearing here and there between the cut edges of two ordinary circumferential laminæ.

Finally, spaces are occasionally seen in a section of bone, which are characterized by an eroded outline, but in some cases they may be partially filled up by concentric lamellæ. These were named "Haversian spaces" by Tomes and de Morgan, and they are interpolated or intruded amongst the regular Haversian systems, some of which may have been cut in upon in the excavation of the

space. It was further noticed by Tomes and de Morgan that the spaces in question may sometimes be seen being filled up at one part by the deposition of lamellæ, whilst they are extending themselves by absorption at another. The Haversian spaces are most numerous in young and growing bones, but they occur also after growth is completed.

The three appearances above mentioned are due to the peculiar manner in which the absorption of bone occurs; for it is effected, as will presently be described, by

Fig. 97

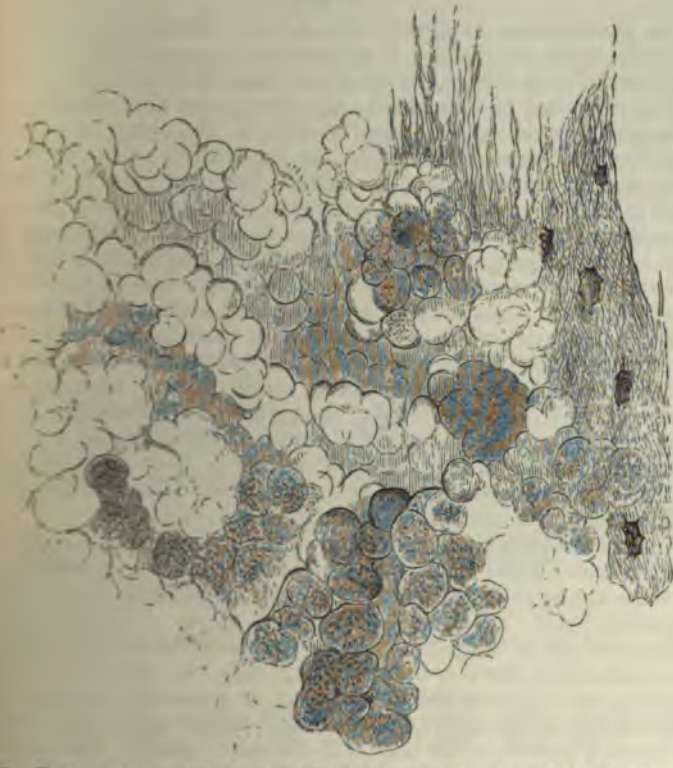


Fig. 97.—Portion of a nodulated layer of bone-tissue from near the surface of the shaft of a decalcified humerus (Sharpey).

At one side shreds of fibrous lamellæ are seen in the figure. Magnified 300 diameters. From a drawing by Allen Thomson.

the agency of large multinucleated cells, which excavate little hemispherical pits in the osseous tissue. If the process of absorption should cease and should be succeeded by a re-deposition of osseous substance, the new osseous matter filling up the hollows of the absorbed surface exhibits, when it is detached, a raised impression corresponding with the hollows into which it fitted.

In young bones the lamellar character is far less distinct than in adult bones, the tissue being constituted chiefly of bundles of fibres which interlace in every direction in the ground substance; in this reticular form of osseous tissue the lacunæ are both more numerous and irregular than in lamellated bone.

When, as is often the case, tendons become ossified, little but a calcification of the ground substance of the tendon occurs, so that, after decalcifying, the tendinous structure again becomes manifest.

The exact knowledge we possess of the minute structure of osseous tissue is largely the result of the careful and laborious research of the late Professor Sharpey, whose account, published in the fifth edition of this work in 1845, has needed no erasure, and but little addition, even to the present day. His labours in this field have been to a certain extent recognized in the adoption of the name "fibres of Sharpey" for the perforating fibres discovered by him, but it is only now, after the lapse of many years, that the facts which he demonstrated are becoming understood and their significance appreciated by histologists.

THE PERIOSTEUM.

The **periosteum**, as already stated, is a fibrous membrane which covers the bones externally. It adheres to them very firmly, and invests every part of their surface, except where they are covered with cartilage.

It is composed of two layers; the outer, consisting chiefly of white fibres, and containing occasional fat-cells, is the means of supporting numerous blood-vessels destined for the bone, which ramify in the membrane, and at length send their minute branches into the Haversian canals of the compact substance, accompanied by processes of filamentous tissue derived from, or at least continuous with, the periosteum. The inner layer is largely made up of elastic fibres, frequently in several distinct strata. Between it, however, and the proper osseous tissue there is a fibrous stratum containing in the young bone a number of granular corpuscles (osteoblasts), while in the adult bone these have become flattened out into an epithelioid layer covering the osseous substance, and are in many places separated by a cleft-like space (serving probably for the passage of lymph) from the rest of the periosteum (Schwalbe).

By treating the membrane with nitrate of silver, lymphatics are discovered in it accompanying the blood-vessels in the outer layer; and, as in other aponeurotic structures, extensive epithelioid markings, covering a great part of the surface, are brought into view.

Fine nerves spread out in the periosteum; they are chiefly associated with the arteries, and for the most part destined for the subjacent bone; but some are for the membrane itself, and some of these end in Pacinian corpuscles.

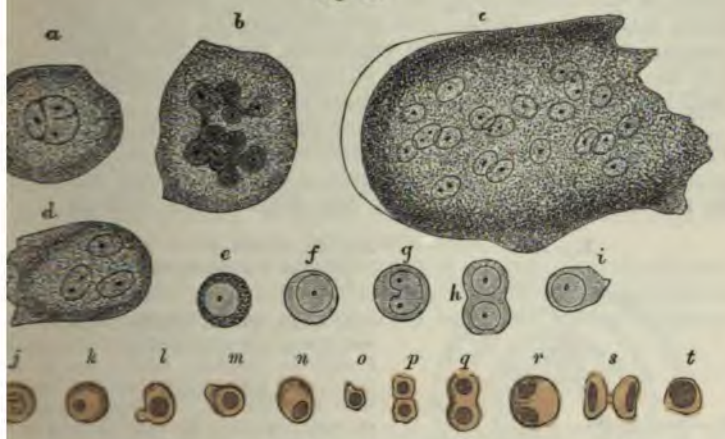
The chief use of the periosteum is to support the vessels going to the bone, and afford them a bed in which they may subdivide into fine branches, and so enter the dense tissue at numerous points. Hence, when the periosteum is stripped off at any part, there is great risk that the denuded portion of the bone will die and exfoliate. The periosteum also contributes to give firmer hold to the tendons and ligaments where they are fixed to bones. Its relation to the growth and renewal of bone will be referred to later on.

THE MARROW.

The **marrow** (*medulla ossium*) is lodged in the interior of the bones; it fills up the hollow shaft of long bones and occupies the cavities of the cancellated structure; it extends also into the Haversian canals—at least into the larger ones—along with the vessels. A fine layer of a highly vascular areolar tissue lines the medullary canal, as well as the smaller cavities which contain marrow; this has been named the medullary membrane, internal periosteum, or endosteum; but it cannot be detached as a continuous membrane. Its vessels partly supply the contiguous osseous substance, and partly proceed to the clusters of adipose

les, among which there is but very little connective tissue, in conse-
ce perhaps of their being contained and supported by bone.
ıe marrow differs considerably in different situations. Within the
of the long bones it is of the character of ordinary adipose tissue,
he fat-cells are supported by a kind of retiform tissue, and between
elements occur similar to those immediately to be mentioned in the
ıarrow. In short bones, and in the cancellated ends of long bones,
especially in the cranial diplöe, the bodies of the vertebræ, the
um, and the ribs, the marrow is red or reddish in colour, of more fluid
stence, and with very few fat-cells. While, however, the fat-cells are
y in the red-coloured marrow, it contains numerous roundish nucleated
—the proper *marrow-cells* of Kölliker (fig. 98, *e*—*i*). These in general
ırance resemble the pale corpuscles of the blood, but are larger, with
ırer protoplasm and a relatively larger nucleus. Like the pale cor-
es, they exhibit amœboid movements. Amongst them are smaller
which present a reddish colour, and resemble in appearance the
itive nucleated corpuscles of the embryo (fig. 98, *j*—*t*); these are the
which have been described as representing transitional forms between
ıroper marrow-cells and red blood-disks (vide ante, p. 37).

Fig. 98.



g. 98.—Cells of the red marrow of the guinea-pig. Highly magnified. (E. A. S.)

a large cell the nucleus of which appears to be partly divided into three by constric-
; *b*, a cell the enlarged nucleus of which shows an appearance of being constricted
a number of smaller nuclei; *c*, a so-called giant-cell or myeloplaxe with many
; *d*, a smaller myeloplaxe with three nuclei; *e*—*i*, proper cells of the marrow;
various forms of coloured nucleated cells.

ther cells have occasionally been noticed containing one or more red
uscles in their interior: whether these have been developed *in situ*
manner similar to that previously described in connective tissue
uscles of the young animal, or have been taken into the interior of
mœboid cell, there to be transformed into pigment granules, is not
inly known. Cells containing reddish pigment granules are, how-
not uncommon. There further occur in the marrow, especially in
ıeighbourhood of the osseous substance, large multi-nucleated proto-

plasmic masses (*myeloplaxes*, Robin (fig. 98, *a—d*)), which, as pointed out by Kölliker, appear to be more especially concerned with the process of absorption of bone, under which head they will subsequently be further alluded to. The myeloplaxes vary much in size, but are always larger than the proper marrow-cells. Their nucleus is not always multiple, but when single it is usually enlarged, and presents indications of division (fig. 98, *a*) ; it may even be so constricted as to exhibit an irregularly moniliform appearance (fig. 98, *b*).

THE BLOOD-VESSELS AND LYMPHATICS OF BONE

Blood-vessels.—The bones are well supplied with blood-vessels. A network of periosteal vessels covers their outer surface ; fine vessels run from this through all parts of the compact tissue in the Haversian canals ; others penetrate to the cavities of the spongy part, in which they ramify ; and a considerable artery goes to the marrow in the central part of the bone. In the long bones this *medullary artery*, often, but improperly, called "the nutritious artery," passes into the medullary canal, near the middle of the shaft, by a hole running obliquely through the compact substance. The vessel, which is accompanied by one or two veins, then sends branches upwards and downwards to the marrow and medullary membrane in the central cavity and the adjoining Haversian canals ; from these branches capillaries pass radially towards the periphery. The comparatively narrow arterial capillaries pass suddenly into the wide venous ones, so that the current of blood must be considerably retarded both in these and in the large thin-walled veins.

The ramifications of the medullary artery anastomose with the arteries of the compact and cancellated structure ; indeed, there is a free communication between the finest branches of all the vessels which proceed to the bone, and there is no strictly defined limit between the parts supplied by each. In the thigh bone there are frequently two medullary arteries entering at different points.

Fig. 99.

Fig. 99.—Section of a Haversian canal, showing its contents. Highly magnified. (E.A.S.)

a, small arterial capillary vessel ; *v*, large venous capillary ; *n*, pale nerve-fibres cut across ; *l*, cleft-like lymphatic vessel : one of the cells forming its wall communicates by fine branches with the branches of a bone-corpuscle. The substance in which the vessels run is connective tissue with ramified cells ; its finely granular appearance is probably due to the cross section of fine fibrils.

Most of the Haversian canals contain two small blood-vessels, arterial and venous (fig. 99), together with a small amount of delicate connective tissue containing branched cells which are flattened close to the bone, and communicate by their branches with the ramifications of the bone-corpuscles.

The veins of the cancellated texture are peculiar and deserve special notice. Their arrangement is best known in the bones of the skull, where, being lodged in the diplöe or spongy texture between the outer and inner compact tables, they have received the name of the diplöic veins. They are large and numerous,

and run separately from the arteries in canals formed in the cancellated structure, the sides of which are constructed of a thin lamella of bone, perforated here and there for the admission of branches from the adjoining cancelli. Being thus inclosed and supported by the hard structure, the veins have exceedingly thin coats. They issue from the bone by special apertures of large size. A similar arrangement is seen in the bodies of the vertebræ, from whence the veins come out by large openings on the posterior surface. In the long bones numerous apertures may be seen at the ends, near the articular surfaces; some of these give passage to arteries, but the greater number, as well as the larger of them, are for the veins of the cancellated texture, which run separately from the arteries.

According to Hoyer and Rindfleisch the venous capillaries and veins of the red marrow have incomplete walls, or rather are channels bounded only by the medullary parenchyma, so that the blood-corpuscles which are being formed from marrow-cells can readily get into the circulation. Langer, on the other hand, found the vascular system of the marrow to be a closed one. That the channels in which the blood flows are bounded by elongated cells, similar to those of capillaries in other situations, it is easy, Rindfleisch notwithstanding, to see, but at the same time it must be admitted that the extreme ease with which these cells separate from one another betokens the lack of a complete union between them, and a greatly increased permeability of the vascular wall in consequence.

The blood coming from the marrow possesses a large number of pale corpuscles, as well as nucleated red corpuscles.

Lymphatics.—In addition to the lymphatics in the periosteum (which have already been mentioned), there are others in the Haversian canals accompanying the vessels (fig. 98, *l*), and often partially or wholly 99
inclosing them (perivascular). The lymph or plasma of the blood is enabled to penetrate the hard bony substance by means of the lacunæ and communicating canaliculi, which appear to bear the same relation to the lymphatics as do the cell-spaces of ordinary connective tissue to the lymphatics of that tissue.

The fine **nerves** which may be seen entering the bones along with the arteries are probably chiefly destined for those vessels; it is not known whether any end in the bony tissue itself.

As far as can be judged from observations on man and experiments on the lower animals, the bones, as well as their investing periosteum, are scarcely if at all sensible in the healthy condition, although they are painfully so when inflamed.

FORMATION AND GROWTH OF BONE.

The foundation of the skeleton is laid at a very early period; for, among the parts that appear soonest in the embryo, we distinguish the rudiments of the vertebræ and base of the skull, which afterwards form the great median column to which the other parts of the bony fabric are appended. But it is by their outward form and situation only, that the parts representing the future bones are then to be recognised; for at that early period they do not differ materially in substance from the other structures of the embryo, being made up of mesodermic cells, with a small amount of intercellular substance. Very soon, however, they become cartilaginous, and ossification in due time beginning in the cartilage and continuing to spread from one or from several points, the bony tissue becomes gradually formed.

But, while it is true with respect to the bones generally that their ossification commences in cartilage, it is not so in every instance. The tabular bones forming the roof of the skull may be adduced as a decided example to the contrary; in these the ossification goes on in connective

tissue altogether unconnected with any cartilage; and even in the long bones, in which ossification undoubtedly commences and to a certain extent proceeds in cartilage, it will be afterwards shown that there is much less of the increment of the bone really owing to that mode of ossification than was at one time generally believed. It is necessary, therefore, to distinguish two species or modes of ossification, which for the sake of brevity may be called the *intramembranous* and the *intracartilaginous*.

INTRAMEMBRANOUS OSSIFICATION: OSSIFICATION IN CONNECTIVE TISSUE.

The tabular bones of the cranium, as already said, afford an example of this mode of ossification. The base of the skull in the embryo is cartilaginous; but in the roof, that is to say, the part comprehending the parietal, the frontal, and a certain portion of the occipital bones, we find (except where there happen to be commencing muscular fibres) only the integuments, the dura mater, and an intermediate layer, in which the ossification proceeds.

The commencing ossification of the parietal bone, which may be selected as an example, appears to the naked eye in the form of a network in which the little bars or spicula of bone run in various directions, and meet each other at short distances. By-and-by the ossified part, becoming extended, gets thicker and closer in texture, especially towards the centre, and the larger bony spicula which now appear, run out in radiating lines to the circumference. The ossification continues thus to spread and consolidate until the parietal meets the neighbouring bones, with which it is at length united by sutures.

Fig. 100.

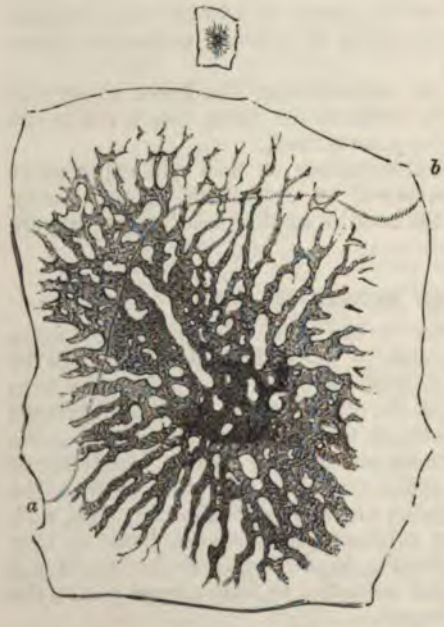


Fig. 100.—PARIETAL BONE OF AN EMBRYO SHEEP. SIZE OF THE EMBRYO, 2½ INCHES. (Sharpey.)

The small upper figure represents the bone of the natural size, the larger figure is magnified about 12 diameters. The curved line, *a*, *b*, marks the height to which the subjacent cartilaginous lamella extended. A few insulated particles of bone are seen near the circumference, an appearance which is quite common at this stage.

Fig. 100 represents the parietal bone of an embryo sheep about two inches and a half long, and shows the character of the ossification as it appears when the object is magnified about twelve diameters. The bone is formed in membrane as in the human fœtus, but a thin plate of cartilage rises up on its inside from the base of the skull. The ossification, however, is decidedly unconnected with the cartilage, and goes on in a membrane lying outside of it.

When further examined with a higher magnifying power, the tissue or membrane in which the ossification is proceeding, appears to be made up of fibres and granular corpuscles, with a ground substance between, and, in point of structure, may not unaptly be compared to connective tissue in a certain stage of development. The corpuscles are large and angular, and they are densely packed all over the area of ossification, covering the bony spicula, and filling up their interstices.

On observing more closely the points of the growing osseous rays at the circumference of the bone, where they shoot out into the soft tissue, it will be seen that the portion of them already calcified is granular and rather dark in appearance (fig. 101), but that this character is gradually

Fig. 101.

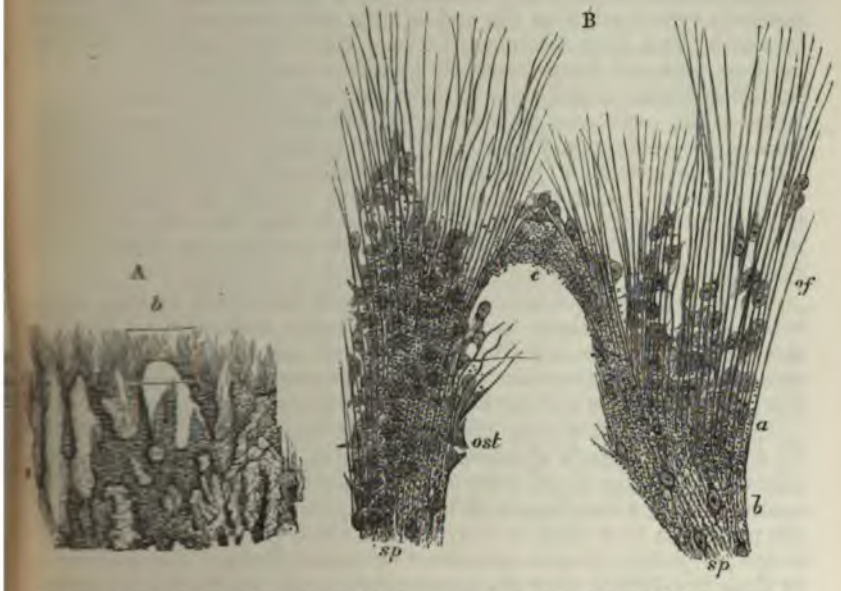


Fig. 101.—Part of the developing parietal bone of a foetal cat (1½ inch long). (From drawings by Mr. J. Lawrence.) (E.A.S.)

A, a piece of the growing edge slightly magnified, showing the bony spicules terminated by branches of osteogenic fibres; *a*, an isolated bony spicule united to the main part of the ossification by a bundle of osteogenic fibres.

B, the part marked *b* of the smaller figure, highly magnified; *sp*, bony spicules, with some of the osteoblasts imbedded in them, producing the lacunæ; *ost*, osteoblasts partly imbedded in the newly formed bone; *of*, osteogenic fibres prolonging the spicules, with osteoblasts between them and applied to them; *a*, granules of calcareous deposit between the osteogenic fibres; at *b* the granules have become blended, and the matrix is clearer; at *c* a continuity is established between the two adjacent spicules.

lost as they are traced further outwards in the membrane, in which they are prolonged for a little way in form of soft and pliant bundles of transparent fibres (fig. 101, B, *of*).

These are termed *osteogenic fibres*, the soft transparent matter of which they are composed being known as osteogenic substance, or simply as *osteogen*. They exhibit faint fibrillation, and have been compared to bundles of white connective tissue fibres, with which, in some situations,

they appear to be continuous (Gegenbaur). But although similar in chemical composition, they are somewhat different from these in appearance, having a stiffer aspect and straighter course, besides being less distinctly fibrillated. The fibres become calcified by the deposition within them of earthy salts in the form of minute globules, which produce a darkish granular opacity, until the interstices between the globules also become calcified, and the minute globules becoming thus fused together, the new bone again looks comparatively clear (fig. 101, B, b).

As already stated the fibrils themselves are not calcified, but the calcification affects the portion of matrix which unites them into the osteogenic fibres, so that these may be described as being calcified.

The bundles of osteogenic fibres which prolong the bony spicules generally spread out from the end of each spicule so as to come in contact with those from adjacent spicules. When this happens, the innermost or proximal fibres frequently grow together (fig. 101, B, *c*), whilst the other fibres partially intercross as they grow further into the membrane. The ossific process extends into the osteogenic fibres *pari passu* with their growth, and thus new bony spicules become continually formed by calcification of the groups or bundles of osteogenic fibres.

The earthy deposit not only involves the osteogenic fibres, but also the ground-substance of the tissue in which they lie. It occasionally appears in an isolated patch here and there on some of the osteogenic fibres in advance of the main area of ossification (see fig. 101, A, *a*).

The osteogenic fibres become comparatively indistinct as they and the substance between them calcifies; they appear, however, to persist in the form of decussating fibres, such as are seen in the adult bone, although in the embryonic bone their disposition is less lamellated, the bony matter having a somewhat coarsely reticular structure.

In this way the first bony matter becomes formed as a perforated plate or network of osseous spicules, which, whilst becoming extended peripherally in the way above described, gradually becomes thicker nearer the centre, partly by the deposit of bony matter upon its surfaces, partly by the projection from them of bony spicules which are prolonged like those at the periphery by similar systems of osteogenic fibres. The perforations in these first-formed bony plates correspond to the bays which were seen between the advancing spicules, and to the meshes of the bony network formed afterwards by the junction of the spicules, and as the bone thickens they become enclosed and converted into reticulating interstices (like the canals of a sponge), which are occupied by blood-vessels, and by the corpuscles before mentioned. These corpuscles also everywhere cover the osteogenic fibres, to which their flattened sides are often applied (Fig. 101, B, *ost*). Where the osteogenic fibres diverge from one another, the intervals are occupied by the same cells. It is probable that the osteogenic substance is formed by the agency of the cells in question, hence the name "osteoblasts" was assigned to them by Gegenbaur. Some of the osteoblasts are involved in the ossifying matrix, and remain as the corpuscles of the future bone, the spaces enclosing them being the lacunæ. It is supposed that the canaliculi, which are at first short, are afterwards extended by absorption, so as to anastomose with those of neighbouring lacunæ.

It is believed by many histologists that the fibrillated ground-substance of bone is formed not outside the cells in an intercellular substance, but by a direct

n of the protoplasm of some of the osteoblasts into bony tissue. If this case, there ought to be some indication in the formed osseous substance l-areas of which it was made up, but nothing of the kind has been exist. There should moreover often be observed osteoblasts which partly converted into bony substance, but this has also never been . And if as some suppose, the peripheral part of each osteoblast converted into osseous substance, while the central part and nucleus s the corpuscle within a lacuna, the osteoblasts would have to be far larger than the permanent lacunæ, which is certainly not the e view in question is similar to that which supposes ordinary connective have a like origin, and appears to rest more upon theory than on actual m of the stages of the developmental process.

while, the meshes of the bony network, which were occupied as seen by one or more blood-vessels, and by numerous osteoblasts, diminished in extent, and their walls, which were formed by the trabeculæ, at the same time increased in thickness by the deposit m of irregular bony layers, some of the osteoblasts remaining the layers, and forming the corpuscles and lacunæ as before. erstices of the bony spongework thus become gradually con- nto narrow channels in the osseous substance, containing one blood-vessels surrounded by osteoblasts.

ter stage the increase in thickness takes place by successive depositions amellæ, under the periosteum, a concentric deposition occurring at the e on the walls of the vascular channels. But since the growth in of a membrane-bone takes place in exactly the same manner as that of long bones, which will be fully described in a subsequent page, the referred to the account of the process there given.

be observed that the appearance of the ossifying membrane-bone in the a network of trabeculæ seems to be determined by the pre-existence of : network in the embryonic tissue. The new bone everywhere makes its e in the spots which are furthest from the vessels, and the bony net- ywhere alternates with the vascular network. At the edges of the g bone the spicules which prolong it pass between, and avoid the blood-vessels, which are thus left in the bays between the spicules: gent bunches of osteogenic fibres which prolong the adjacent spicules the enclosure of the blood-vessel.

time the membrane-bone extends so as almost to come into contact neighbouring bones. But as long as growth continues, there always n the situation occupied afterwards by the sutures a vascular connective h numerous osteoblasts. This is continually on the increase, but as fast rs, the osteogenic fibres and the osseous spicules extend into it from the nes on either side. At length, however, when these have attained their nsions, the growth of the intermediate tissue ceases, and it becomes ly invaded by the bone on either side, with the exception of the narrow ular line of suture, which may eventually itself become more or rated.

OSSIFICATION IN CARTILAGE.*

already been stated that, in by far the greater number of bones dermic tissue with closely packed cells, of which they originally is very quickly succeeded by cartilage, in which the ossification

ent varieties of ossification in connection with cartilage are met with in the , and these are distinguished by comparative morphologists by special names. n the calcareous deposit occurs immediately outside the perichondrium it is *ostosis;* immediately under the perichondrium, and eating into the cartilage, within the substance of the cartilage-matrix, *endostosis*, which again may be rficial, or central (Parker & Bettany, Morphology of the Skull).

begins. One of the long bones taken from a very small embryo, just before ossification has commenced in it, is observed to be distinctly cartilaginous. In the tibia of a sheep, for example, at a time when the whole embryo is

Fig. 102.

Fig. 102.—Humerus of a fœtus, natural size. (Sharpey.)

The upper half is divided longitudinally. *a*, cartilage, *b*, line of junction of bone and cartilage. The periosteal bone looks lighter than the endochondral bone proper.

Fig. 103.

Fig. 103.—Section of phalangeal bone of human fœtus, at the time of commencing ossification. From a preparation by Mr. F. A. Dixey. Magnified about 75 diameters. (E. A. S.)

The cartilage cells in the centre are enlarged and separated from one another by dark-looking calcified matrix; *im*, layer of bone deposited underneath the periosteum; *o*, layer of osteoblasts by which this layer has been formed. Some of the osteoblasts are already embedded in the new bone as lacunæ. The cartilage-cells are becoming enlarged and flattened and arranged in rows above and below the calcified centre. At the ends of the cartilage the cells are small and the groups are irregularly arranged; the fibrous periosteum is not sharply marked off from the cartilage.

not more than an inch and a quarter in length, we can plainly see that the substance consists of cartilage-cells imbedded in a pellucid matrix. These cells can scarcely be said to be collected into groups, and are very irregular in size and shape. They become enlarged in the middle

e shaft when ossification is about to commence. As it grows, the acquires firmer consistence; it represents in figure the future ugh of course much smaller in size, and it is surrounded brous membrane, the future periosteum. Vessels ramify in brane, but none are seen in the cartilage until ossification is begin. In a long bone the ossification commences in the id proceeds towards the ends, which remain long cartilaginous, ented in fig. 102. Much later, separate points of ossification them, and form epiphyses, which at last are joined to the body ne.

anner in which the process of ossification of a cartilage bone e is as follows:—

middle of the cartilage the cells are enlarged, and are separated another by a relatively larger amount of matrix than elsewhere This matrix becomes hardened by calcareous deposit, assumes ar opaque appearance, and has a gritty feel to the knife. e the cartilage-cells above and below the centre of ossification nlarged and flattened, and piled up in elongated groups or which radiate from the centre for a certain distance towards . The columns taper towards their ends, where the cartilage- h compose them are smaller. Into the matrix between these oups the calcareous deposit extends between and around s of cells, so that the calcified substance encloses the columns; paces in the calcified matrix which are still occupied by the ells, either singly or in elongated groups, being termed the *areolæ* (Sharpey). Simultaneously with this deposit in the natrix, a layer of osseous substance (fig. 103, *im*) is becoming n the outside of the cartilage underneath the periosteum. is a vascular membrane, containing numerous osteoblasts (*o*), chiefly collected on the inner surface next to the carti- it is by their agency that the bony layer on the surface tilage is formed and becomes increased both in thickness and The bony layer, when viewed on the surface, shows the usual t fibres of bony lamellæ, and as other layers are deposited upon become formed between them by the inclusion of some of the s. In this first stage of ossification, we see therefore two pro- ng on, a deposit of earthy matter in the matrix of the cartilage, of which assume a highly characteristic arrangement, and a n of true membrane-bone, underneath the perichondrium, and vesting the surface of the cartilage.

next happens is an irruption of the subperiosteal vascular oblastic tissue into the middle of the cartilage, one or more being excavated by absorption in the newly deposited mella and the tissue in question passing through these and into the cartilage (fig. 104, *ir*). Here it absorbs art of the calcified matrix, and by demolishing in this s of the walls of the primary areolæ, forms larger spaces *dary areolæ* of Sharpey, the *medullary spaces* of H. Müller) filled by embryonic marrow, consisting of ramified cells and s, the cartilage-cells which occupied the primary areolæ dis- before it. All the middle of the calcified temporary cartilage hus excavated with large spaces and replaced by the vascular ic tissue. As the calcification of the cartilage-matrix extends

towards the ends of the shaft, proceeding always in the same manner the osteoblastic tissue closely follows, and after supplanting the cartilage-cells in the primary areolæ, absorbs parts of their walls so as to throw two or more together to form secondary areolæ ; in this way a great part of the primary bone (or calcified cartilage-matrix) is at once removed.

Fig. 104.

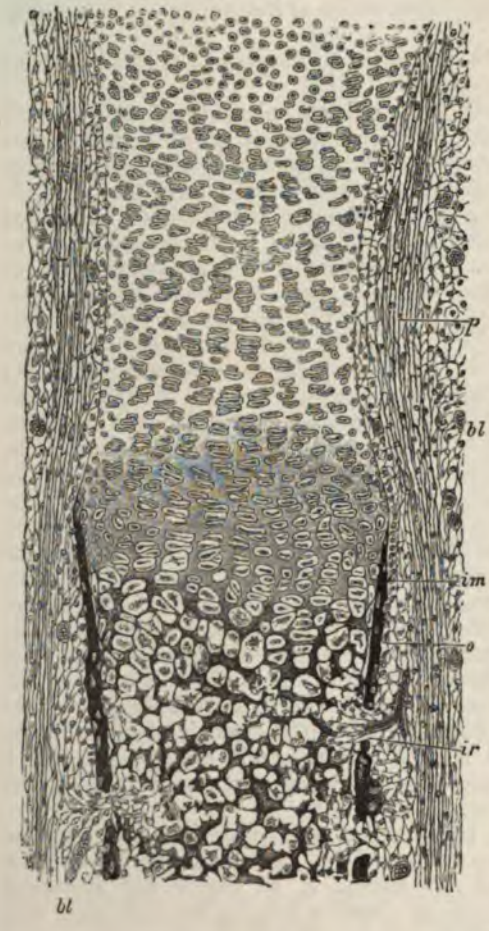


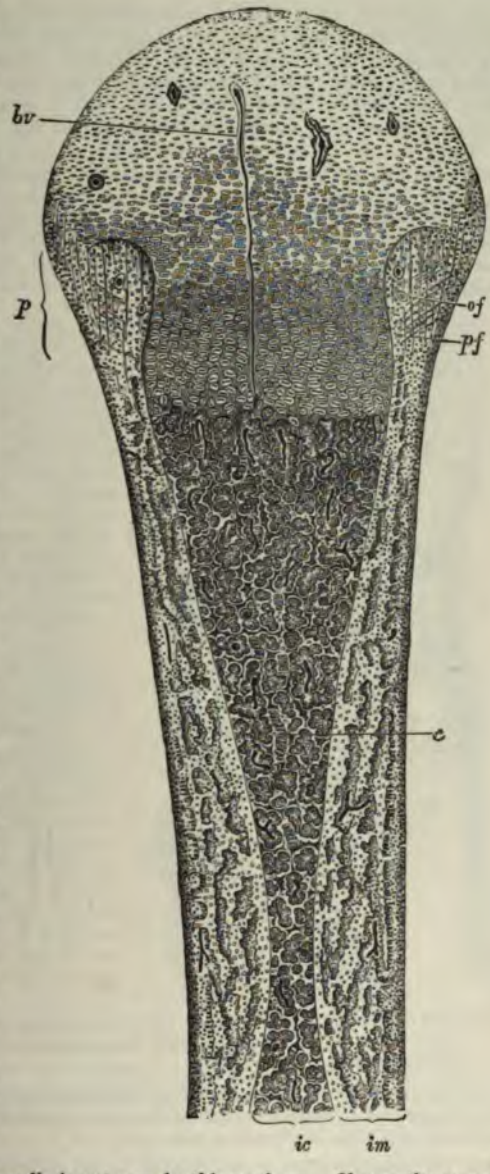
Fig. 104.—SECTION OF PART OF ONE OF THE LIMB BONES OF A FŒTAL CAT, AT A RATHER ADVANCED STAGE OF OSSIFICATION THAN IS REPRESENTED IN FIG. 103, AND SOMEWHAT MORE HIGHLY MAGNIFIED. (Drawn by Mr. J. Lawrence.) (E. A. S.)

The calcification of the cartilage matrix has advanced from the centre, and is extending between the groups of cartilage cells which are now arranged in characteristic rows. The subperiosteal bony deposit (*im*) has extended *pari passu* with the calcification of the cartilage-matrix. The cartilage-cells in the primary areolæ are mostly shrunken and stellate, in some cases they have dropped out of the space. At *ir* and in two other places an irruption of the subperiosteal tissue, composed of ramified cells with osteoblasts and growing blood-vessels, has penetrated the subperiosteal bony crust, and has begun to excavate the secondary areolæ or medullary spaces ; *p*, fibrous layer of the periosteum ; *o*, layer of osteoblasts, some of them are embedded in the osseous layer as bone corpuscles in lacunæ ; *bl*, blood-vessels occupied by blood-corpuscles. B, beyond the line of ossific advance the periosteum may be noticed to be distinctly incurved. This incurvation is gradually moved on, the cartilage expanding behind it until the head of the bone is reached, when it forms the periosteal notch or groove represented in fig. 105, *p*.

At a short distance below the advancing ossification, the medullary spaces become at first somewhat more enlarged by further absorption, but at the same time their walls (which were at first formed only by the remains of the walls of the primary areolæ and therefore only by calcified cartilage-matrix) begin to be thickened by the deposition of layers of new bone, and this deposition increases gradually towards the middle of the shaft (compare fig. 108, *c* and *d*). The lacunæ first appear in this deposit, there are of course none in the

cartilage. Moreover as layer after layer is deposited upon the the medullary spaces these become gradually narrowed into

Fig. 105.



-LONGITUDINAL SEC-
ROUGH THE UPPER
F THE DECALCIFIED
S OF A FŒTAL SHEEP,
NDER A MAGNIFYING
F ABOUT 30 DIAME-
(Drawn by Mr. J.
e.) (E.A.S.)

part of the shaft
primarily ossified
; what remains of
ry bone is repre-
dark, enveloped by
secondary deposit.
of the bone are
y embryonic mar-
osteoblasts, and
ls variously cut,
as dark lines.
straight vessel (*bv*
dvance of the line
tion far into the
s head, most of
loop round close to
e. At one or two
the older parts of
longated groups of
lls (*c*) may still be
have escaped ab-
im, the part of the
as been ossified in
that is to say in the
tissue under the
. It is well marked
e central portion,
nded, peripherally,
edge, the projec-
ich are indistinctly
rolonged by bunches
ic fibres. A row of
covers the superfi-
of the bone. The
al layer is pro-
ve into the thick-
which encroaches
artilage of the head
, and in which are
gst numerous osteo-
a few blood-vessels,
t, longitudinal os-
bres (*of*), and some
(*pf*) crossing them,
aps representing
arpey. The calca-
having been re-
an acid, the gra-
fic deposit passing

the rows of cartilage-cells is not seen in this specimen. Observe the general f the osseous trabeculæ and the vascular channels between them to radiate riginal centre of ossification. This is found to prevail more or less in all bones are first formed, although the direction of the trabeculæ may afterwards become relation with varying physiological conditions, and especially as the result of different directions.

inter-communicating channels, which contain little more than a blood-vessel and some jelly-like embryonic connective tissue (fœtal marrow) with a few osteoblasts applied to the bone.

In the end, some of the enlarged cavities and open structure remain to form the cancellated tissue, but much of this structure is afterwards removed by absorption, to give place to the medullary canal of the shaft. In many of these cavities the walls of the coalesced primary areolæ may long be distinguished, like little arches, forming by their union a sort of festooned outline, upon which the new bony laminæ are deposited (see figs. 105, & 109).

The *primary osseous matter* forming the original thin walls of the areolæ, and produced by calcification of the cartilaginous matrix, is decidedly granular, and has a dark appearance; the subsequent or *secondary deposit* on the other hand is quite transparent, and of a uniform, homogeneous aspect. This secondary deposit begins to cover the granular bone a very short distance below the surface of ossification (see fig. 108), and, as already stated, increases in thickness further down.

Fig. 106.

Fig. 107.

Fig. 106.—TRANSVERSE SECTION OF OSSIFYING CARTILAGE, INCLUDING A PORTION OF THE ADVANCING CALCIFICATION. FROM THE HUMERUS OF A FŒTAL SHEEP, MAGNIFIED 70 DIAMETERS. (Sharpey.)

c, cartilage, the cells of which are enlarged, but the matrix not yet calcified; *b*, primary osseous deposit in the cartilage matrix, extending between the cartilage-cells and enclosing them in primary areolæ.

Fig. 107.—SMALL PORTION OF A SECTION OF DEVELOPING BONE, TAKEN AT THE JUNCTION OF THE BONE AND CARTILAGE, AND EXAMINED IN THE FRESH CONDITION. MAGNIFIED ABOUT 140 DIAMETERS. (Sharpey.)

a, *b*, two of the new-formed osseous tubes or areolæ, with a few shrunken cartilage-—lls lying in them; *c*, cartilage-cells near the ossifying surface, large and clear and ling the cavities in the matrix; on the left of the figure some of them are shrunken.

the limit of advancing ossification, the blood-vessels terminate in capil-
s (see figs. 105, 108) which are often somewhat dilated. It is supposed by
hat these vascular loops by their growth directly produce absorption of the
but it is more probable that this is caused by the agency of some of the
ch accompany the blood-vessels. The absorption of the walls of the
areolæ (calcified cartilage-matrix) seems to be effected by certain large
. 108, *f*,*f*) which from their function have been termed by Kölliker,
s, and which are found wherever bone is being eaten away: we shall
them further on. The secondary bone which thickens the walls of the
y spaces is no doubt formed by the osteoblasts.

Fig. 108.

.—PART OF A LONGITUDINAL OF THE DEVELOPING FEMUR OF BBIT. DRAWN UNDER A MAGNI-POWER OF 350 DIAMETERS (from nd Noble Smith).

s of flattened cartilage-cells; *b*, larged cartilage-cells close to the bone, the matrix between is cified; *c*, *d*, already formed bone, is trabeculæ being covered with s (*e*), except here and there, where ll or osteoclast (*f*), is seen, eroding he trabeculæ; *g*, *h*, cartilage-cells e become shrunken and irregular From the middle of the figure s the dark trabeculæ, which are f calcified cartilage matrix, are covered with secondary osseous deposited by the osteoblasts. ular loops at the extreme limit of are well shown, as well as the appearance of the cartilage-cells.

egard to the destination of the -cells, two opposite views have en by histologists. According which was that adopted by H. and has received most adher- capsules are opened by absorp- the cells are converted, after ng division, into osteoblasts, g to the other, the cartilage- emselves become removed by on, and take no part, directly ectly, in the production of the y bone. The latter view of the vas taken by Lovén, and it was arded by Sharpey as in all pro- the more correct.

ifficult to decide between these All that can be said is that the demarcation between the cartilage-cells and the osteoblastic tissue is gly abrupt (fig. 108), and that the latter often, if not always, terminates y a dilated vascular loop, or it may be by a developing capillary filled ood corpuscles. Except that they are generally much shrunken and in form (at least after death or the action of reagents), the cartilage- w no absorption and no distinct evidence of division, and it may be d that this is also the case when, as sometimes happens, they have not red before the advancing subperiosteal tissue, but remain for a time still g an untouched primary areola (see fig. 105, *c*).

As ossification advances towards the ends of the bone, the portion as yet cartilaginous continues to grow at the same time, increasing in every dimension. The part already osseous increases also in circumference; fresh bone being continually deposited in the subperiosteal membranous tissue outside that which is first formed on the surface of the cartilage (figs. 105, 109). The subperiosteal deposit takes place in the same way as in the formation of a membrane bone. Bony spicules prolonged by bunches of osteogenic fibres (fig. 109, *o*) project out from the previously formed layer, into the intervals between the blood-vessels. By the union of the spicules these become in like manner enclosed in channels whose walls are gradually thickened by deposits of osseous lamellæ, between which some of the osteoblasts are left behind as bone-corpuscles in lacunæ, whilst others remain surrounding the blood-vessels in the vascular channels.

Fig. 109.

Fig. 109.—PART OF A TRANSVERSE SECTION OF A DEVELOPING LONG BONE, RATHER MORE ADVANCED THAN THAT REPRESENTED IN FIG. 105, AND UNDER A HIGHER MAGNIFYING POWER (E. A. S.) FROM A DRAWING BY MR. J. LAWRENCE.

cb, endochondral bone which began as a calcification of the cartilage matrix, parts of which still remain (*c*) covered over by secondary osseous deposit; *o*, secondary areolæ, occupied by vessels, fœtal marrow, and osteoblasts; *pb*, periosteal bone deposited in the form of irregular trabeculæ, prolonged externally by bony spicules passing into bunches of osteogenic fibres. These, which are everywhere covered with osteoblasts, become lost in the external fibrous layer of the periosteum, *p*; *bl*, *bl*, blood-vessels variously cut.

The first formed bony tissue is different in its general appearance from the bony tissue of the adult, being more reticular and less regularly lamellar, and, for a long while, even the shafts of the long bones are rather cancellated, than compact in their texture. The more obviously lamellated condition does not begin to appear until about the sixth month after birth, when the periosteum deposits a succession of entire lamellæ around the embryonic bone. The blood-vessels which pass from the periosteum into the bone, pierce these circumferential lamellæ, but are not at first surrounded with concentric lamellæ, and do not therefore lie in true Haversian canals.* The latter become formed later by absorption taking place around the blood-vessels for some little dis-

* Even in the adult bone it may often be noticed that the blood-vessels which pierce the superficial lamellæ are not enclosed by Haversian systems.

e, succeeded by a re-deposition of concentric lamellæ within the ersian spaces thus formed.

mediately before the occurrence of the lamellar deposition under the steum, the young bone undergoes a process of absorption from the inside. medullary canal becomes thereby enlarged, and the medullary spaces, ularly those near the medullary canal, partaking of this absorption and gement, the result is that at about this period there is less bony matter in tion of the shaft than there was immediately before. To the change in ion Schwalbe has given the name "osteoporosis;" it is followed by a position of osseous lamellæ both on the wall of the medullary canal, n the walls of the medullary spaces of the embryonic osseous tissue.

ce the cartilage grows in every dimension by interstitial expansion, the which is invading it (endochondral bone) becomes gradually wider as the ation advances. It is narrowest near the centre of the shaft where the ss began, and widens gradually towards the ends; it has therefore some- of an hour-glass shape (fig. 105, *i.e.*). The cylindrical form of the shaft is tained, however, by the thickness of the periosteal bone being greater at the

Fig. 110.

110.—LONGITUDINAL SECTION THROUGH THE RIOSTEAL THICKENING OF A BONE AT ABOUT E SAME STAGE OF DEVELOPMENT AS THAT PRESENTED IN FIG. 105. From a drawing by . J. Lawrence. (E.A.S.)

cartilage with the cells in rows; the tissue of eriosteal thickening is sharply marked off from cept near the surface; *p*, outer layer of the steum; *i*, *p*, inner layer of the periosteum or eriosteal tissue, with osteogenic fibres, and blasts. One or two bloodvessels are observed cross.

re (where the deposition of bone first began, has been longest proceeding) than at the . Here it gradually diminishes to a thin r immediately investing that part of the ilage into which the calcification is extend- so that the intramembranous subperiosteal ication on the outside, may be said to closely mpany, if it does not even precede, the ification of the cartilage in the interior. er this investment of periosteal bone, or calcification of the cartilage, seems to hinder lateral expansion of that part of the carti- in which the calcification is proceeding; immediately beyond, the expansion already tioned takes place. By the time that the ossification has advanced to extremities of the shaft, the enlarged and expanded end of the cartilage has nded itself over the subperiosteal layer, so that this, with the accom- ying osteoblastic tissue, now seems to lie in a groove or notch (fig. 105, *p*) he cartilaginous head of the bone (Ranvier). This groove is filled with same tissue as that which underlies the rest of the periosteum, namely a ular tissue with branched cells and osteoblasts and osteogenic fibres. The er are prolonged from the periosteal bone, and have for the most part a itudinal direction (fig. 110).

lood-vessels extend from the newly-formed osseous tissue beyond it into the ilage. The vessels are lodged in excavations or branching canals in the ilage (fig. 105) which also contain granular corpuscles (? osteoblasts). Other ular canals enter the cartilage from its outer surface, and conduct vessels into rectly from the perichondrium.

he formation of osseous tissue, having thus proceeded for some time in the ft, at length begins in the extremities of the bone from one or more inde- dent centres, and extends through the cartilage, leaving, however, a thick

superficial layer of it unossified, which permanently covers the articular ends of the bone. The epiphyses thus formed are separated, as long as growth continues, from the shaft or diaphysis by an intervening portion of cartilage, which is at last ossified, and the bone is then consolidated.

A remarkable exception to the ordinary mode of ossification of the cartilage-bones occurs in the terminal phalanges of the digits. In these the calcification of the cartilage begins at the distal extremity or tip, and the sub-periosteal deposit appears simultaneously at the same point, and forms a cap-like expansion over the end of the phalanx. The irruption of the osteoblastic tissue also first occurs at this place. The expanded portion of the phalanx which bears the nail is formed independently of cartilage.

Growth and Absorption of Bone.—The time of final junction of the epiphyses is different in different bones; in many it does not arrive until the body has reached its full stature. Meanwhile, as above described, the bone increases in length by the ossification continuing to extend into the intervening cartilage, which goes on growing at the same time; and it appears that in the part of the shaft already ossified little or no elongation takes place by interstitial growth. This is shown by an experiment first made by Hales and afterwards by Duhamel and by John Hunter, in which, two or more holes being bored in the growing bone of a young animal at a certain measured distance from each other, they are found after a time not to be farther asunder, although the bone has in the mean while considerably increased in length. On the other hand, if one hole be bored in the epiphysis and another in the shaft, they become distinctly removed from one another with the growth of the bone. Moreover, it is well known that if the intervening cartilage in growing bone be injured by disease or removed by the knife, the growth of the bone in length permanently ceases.

Both Hales and Duhamel in experimenting on the growing tibia of a chicken, observed that the elongation was much greater at the upper end. Humphry has shown that in the arm bones the elongation is greater at the end furthest from the elbow joint, and in the leg bones at the end which is next the knee joint.

In the human subject between the first and the fourth or fifth years, the long bones grow chiefly in length, scarcely at all in thickness.

The shaft of a long bone increases in circumference by deposition of new bone on its external surface, while at the same time its medullary canal is enlarged by absorption from within. This can be determined by two methods of experimenting. Thus, in the first place, a ring of silver or platinum put round the wing bone of a growing pigeon, becomes covered with new bone from without, and the original bone included within it gets thinner, or, according to Duhamel, who first made the experiment, is entirely removed, so that the ring comes to lie within the enlarged medullary canal. Secondly, madder given to an animal along with its food tinges those parts in which deposition of new bone is taking place. The earth of bone appears to act as a sort of mordant, uniting with and fixing the colouring matter; and, as in this way the new osseous growth can be readily distinguished from the old, advantage was taken of the fact by Duhamel, and afterwards by Hunter, in their inquiries as to the manner in which bones increase in size. By their experiments it was shown that when madder is given to a young pig for some weeks, the external part of its bones is deeply reddened, proving that the new osseous matter is laid on at the surface of that previously formed. Again, it was found that, when the madder was discontinued for some time before the animal was killed, an exterior white stratum (the last formed) appeared above the red one, whilst the internal white part, which was situated within the red, and had been formed before any madder was given, had become much thinner; showing that absorption takes place from within. In this last modification of the experiment also, as noted by Hunter, a transverse red mark is observed near the ends of the bone, beyond which they are white; the red part indicating the growth in length during the use of the madder, and the white beyond, that which has taken place subsequently,—thus showing that the increase in length is caused by the addition of new matter to the extremities. Madder administered while the process of formation of the concentric lamellæ of the Haversian systems is going on, colours the interior and recently-formed laminæ, so that in a cross section the Haversian apertures appear surrounded with a red ring.

Flourens, and more recently, Kölliker, have repeated and varied these experiments, and have represented the results in beautiful delineations. Kölliker has, in addition, carefully investigated the microscopic appearances observed in the process of absorption of bone. From the results of his researches (which were in part anticipated by those of Lovén), it would seem that the process is essentially dependent on the presence of large multi-nucleated cells, by him termed "osteoclasts," identical with the "myeloplaxes" of Robin (see p. 100), which excavate, in the part which is undergoing absorption, small shallow pits (*foveolæ*) in which also they lie. These pits were first noticed by Howship: they seem to occur wherever absorption is proceeding, and it is to them that the festooned appearance of the Haversian spaces (p. 96) is due. The osteoclasts (fig. 111) vary in size, but are always many times larger than a blood-corpuscle: in shape they are spheroidal or flattened, with either an even or an irregular outline. Their substance is granular in appearance, and they each contain from two to ten clear round nuclei, but this number may be considerably exceeded, whilst on the other hand, there may be but one large nucleus provided with a number of bud-like projections. The osteoclasts frequently present on the side by which they are in contact with the bone a thickened striated border (fig. 111, *a*), somewhat similar to the well-known thickened base of the columnar epithelium-cells of the intestine. With respect to the origin and destiny of the osteoclasts, they are regarded by Kölliker both

Fig. 111.

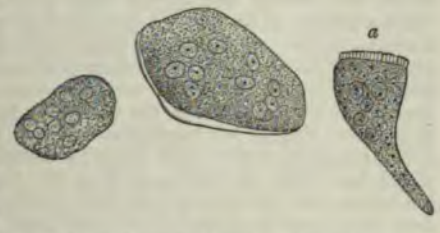


Fig. 111.—THREE OSTEOCLASTS FROM ABSORPTION SURFACES OF GROWING BONE. 400 DIAMETERS (Kölliker).

a, with thickened striated border.

as in the first instance derived from and as eventually breaking up into osteoblasts. Osteoclasts are found in connection with the roots of the milk teeth where these are undergoing absorption to make way for the permanent set; and cells precisely similar occur under pathological conditions in various situations quite apart from any hard tissue, and have long been known as "giant-cells" (Riesenzellen, Virchow.)

The changes of shape which the bones undergo in the process of growth, as well as any changes which may occur in them in adult life, are all produced in the same manner as the increase of size—that is to say, not by interstitial growth and expansion of the substance of the bone in one direction more than in another, but by a deposition of new bone by osteoblasts at some parts and a simultaneous absorption by osteoclasts at others; whilst in other places again neither absorption nor deposition is occurring—just as a modeller corrects his work by laying clay on at one part whilst removing it at another.*

Since during the growth of bones their shape is becoming continually altered, it follows that in nearly all bones during growth there are parts of the bone which are in process of absorption, and others which are in process of more active deposition than the rest. In most of the long bones, towards their ends, absorption is generally taking place at one side, and deposition on the opposite side. The former process may, and probably does, proceed to such an extent, that the endochondral bone may be laid bare or even partially absorbed, but after a while, when the absorption has ceased at any part, re-deposition may take place, the osteoclasts being replaced by osteoblasts, and successive circumferential lamellæ being deposited by these.

A large amount of variation is met with in the different bones of the skeleton

* For special details of this modelling process as it is met with in the different bones of the skeleton, the reader is referred to Kölliker's memoir; Die normale Resorption des Knochengewebes. Leipzig, 1873; and to a paper by Kassowitz (Die normale Ossification &c.) in Stricker's Med. Jahrb. 1879—1880.

in the relative extent to which they are formed in cartilage and in the sub-periosteal tissue respectively. Whereas in some, such as the long bones of the limbs, the endochondral bone is almost entirely removed, as we have seen, and periosteal bone substituted for it; in others, such as the bodies of the vertebræ, a much larger proportion of the adult bone has had an endochondral formation. In one or two bones or parts of bones again, which may be said to have typically an intramembranous origin, cartilage may, according to Kassowitz, become developed under the periosteum at certain places, and the continuation of the ossification may occur in this secondarily developed cartilage. This is said to be the case with the clavicle, the foundation of which is laid in membrane, but which is found at a later period to have cartilaginous ends; and also with the halves of the lower jaw-bone, which is said to develop cartilaginous ends both towards the symphysis and towards the articular and coronoid processes, these cartilaginous ends being altogether distinct from the cartilage of Meckel, which at those parts is unconnected with the jaw-bone, although at another place it is involved in the ossification of the maxilla (see vol. i., p. 74). Kassowitz has described also similar cartilaginous developments in connection with the sub-periosteal tissue at the tuberosity of the radius and the spine of the scapula.

The time of commencement of ossification in the different bones, as well as the number and mode of conjunction of their centres of ossification, have been treated of in the Descriptive Anatomy.

Regeneration of Bone.—In the reunion of fractured bones, osseous matter (which may be preceded by a new formation of cartilage), is formed between and around the broken ends, connecting them firmly together; and when a portion of bone dies, a growth of new bone very generally takes place to a greater or less extent, and the dead part is thrown off. The importance of the periosteum in the process of repair is shown by the fact that if a portion of periosteum be stripped off, the subjacent bone will be liable to die and exfoliate; conversely, if a large part or the whole of a bone be removed and the periosteum at the same time be left intact, the bone will, in a great measure, be regenerated. Osseous formation will even occur in connection with portions of periosteum which have been stripped away from the bone itself and intertwined amongst the muscles of the part, or even with portions that have been entirely removed from a bone and transplanted to a soft tissue. (Ollier.)

It is doubtful if the marrow-tissue can assist in the regeneration of bone. Experiments which have been made to determine this point would seem to show that although in the young bone, where the osteoblasts still retain their osteogenic function, the medullary tissue may take an active part in the formation of the first-formed new bone or "callus," in the adult no such participation of the marrow in the regeneration of bone takes place.

In the young subject even small pieces of the bone itself can be transplanted, and McEwen has succeeded in renewing the greater part of the excised humerus of a child by the introduction, at successive periods, of portions of fresh bone removed from another patient.

It was long supposed that all the bones of the skeleton were preceded by and deposited in cartilage. Nesbitt, however, showed in 1736 that some of the flat bones were formed independently of cartilage, and he further maintained that the cartilage is "entirely destroyed;" he therefore considered it to be a mere temporary substitute; but the steps of the process of intracartilaginous ossification as now traced with the aid of the microscope were unknown to him, and it was not until the year 1846 that the manner of formation of bone and the extensive replacement of the primarily ossified cartilage by new bone formed in membrane was made clear by the researches of Sharpey, who published the results of his work in the fifth edition of this book.

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MUSCULAR TISSUE.

The muscular tissue is that by means of which the active movements of the body are produced. It consists of fibres, which are for the most part collected into distinct organs called "muscles," and in this form it is familiarly known as the flesh of animals. These fibres are also disposed round the sides of cavities and between the coats of hollow viscera, forming strata of greater or less thickness. The muscular fibres are endowed with contractility, by virtue of which they shrink or contract more or less rapidly under the influence of certain causes which are capable of exciting or calling into play the property in question, and which are therefore named stimuli. A large class of muscles, comprehending those of locomotion, respiration, expression, and some others, are excited by the stimulus of the will, or volition, acting on them through the nerves; these are therefore named "voluntary muscles," although some of them habitually, and all occasionally, act also in obedience to other stimuli. There are other muscles or muscular fibres which are entirely withdrawn from the control of the will, such as those of the heart and intestinal canal, and these are accordingly named "involuntary." These two classes of muscles differ not only in the mode in which they are excited to act, but also to a certain extent in their anatomical characters; and on this account we shall consider the structure of each class separately.

STRUCTURE OF VOLUNTARY MUSCLES.

The voluntary muscular fibres are for the most part gathered into distinct masses or muscles of various sizes and shapes, but most generally of an oblong form, and furnished with tendons at each extremity, by which they are fixed to the bones.

The muscular fibres are collected into packets or bundles, of greater or less thickness, named *fasciculi* or *lacerti* (fig. 112). The fibres are parallel in the fasciculi; and the fasciculi extend continuously from one terminal tendon to the other, unless in those instances, like the rectus muscle of the abdomen and the digastric of the inferior maxilla, in which the fleshy part is interrupted by interposed tendinous tissue. The fasciculi also very generally run parallel, and, although in many instances they converge towards their tendinous attachment with various degrees of inclination, yet in the voluntary muscles they do not interlace with one another.

An outward investment or sheath of areolar tissue (*perimysium*) surrounds the entire muscle, and sends partitions inwards between the fasciculi; furnishing to each of them a special sheath. The areolar tissue extends also between the fibres (*endomysium*), but does not afford to each a continuous investment, and therefore cannot be said to form sheaths for them. Every fibre, it is true, has a tubular sheath; but this, as will be afterwards explained, is not composed of areolar tissue. The perimysium contains elastic as well as white fibres; but the elastic element is found principally in its investing (as distinguished from its penetrating) portion. In the endomysium numerous plasma-cells are found. The chief uses of the areolar tissue are to connect the fibres and fasciculi together, and to conduct and support the blood-vessels and nerves in their ramifications between the parts. The relation of these

different subdivisions of a muscle to each other, as well as the shape of the fasciculi and fibres, is well shown in transverse section (figs. 112 and 113).

Fig. 112.

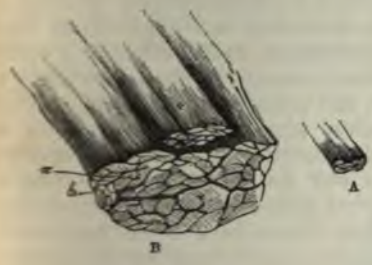

Fig. 113.

Fig. 112.—A, SMALL PORTION OF MUSCLE, CONSISTING OF LARGER AND SMALLER FASCICULI, NATURAL SIZE; B, THE SAME MAGNIFIED 5 DIAMETERS, SHOWING A TRANSVERSE SECTION (Sharpey).

Fig. 113.—A FEW MUSCULAR FIBRES, BEING PART OF A SMALL FASCICULUS, MORE HIGHLY MAGNIFIED (Sharpey).

a, end view of *b*, *b*, fibres; *c*, a fibre split into fibrils.

Fasciculi.—The fasciculi are of a prismatic figure, and their sections have therefore an angular outline (fig. 112). The number of fibres of which they consist varies, so that they differ in thickness, and a large fasciculus may be divisible into two or three orders of successively smaller bundles, but of no regularly diminishing magnitude. Some muscles have large, others only small fasciculi; and the coarse or fine texture of a muscle, as recognized by the dissector, depends on this circumstance. The length of the fasciculi is not always proportioned to the length of the muscle, but depends on the arrangement of the tendons to which their extremities are attached. When the tendons are limited to the ends of a long muscle, as in the sartorius, the fasciculi, having to pass from one extremity to the other, are of great length; but a long muscle may be made up of a series of short fasciculi attached obliquely to one or both sides of a tendon, which advances some way upon the surface or into the midst of the fleshy part, as in the instances of the rectus muscle of the thigh, and the tibialis posticus. Many short fasciculi connected thus to a long tendon, produce by their combined operation a more powerful effect than a few fasciculi running nearly the whole length of the muscle; but by the latter arrangement the extent of motion is greater, for the points of attachment are moved through a longer space.

Fibres; their figure and measurement.—In shape the fibres are cylindrical, or prismatic with rounded angles. Their size is on the whole pretty uniform, although fibres occur here and there in a muscle which differ greatly in size from the prevailing standard. According to measurements by Kölliker in different regions of the body, the prevailing size of the fibres in the muscles of the trunk and limbs is

from $\frac{1}{750}$ to $\frac{1}{400}$ of an inch, but is less in those of the head, especially in the facial muscles, in which he found the diameter to range from $\frac{1}{170}$ down to $\frac{1}{2400}$ of an inch.

Fig. 114.

Fig. 114.—A BRANCHED MUSCULAR FIBRE FROM THE FROG'S TONGUE, MAGNIFIED 350 DIAM. (Kölliker.)

The fibres composing a muscle are of limited length, generally not exceeding one inch and a half; and accordingly in a long fasciculus a fibre does not reach from one tendinous attachment to the other, but ends with a rounded extremity, invested with its sarcolemma, and cohering with neighbouring fibres. Unless when either is fixed to a tendon, both extremities of the fibre terminate in the way described, so that it has a long cylindrical shape. In some muscles, e.g. the sartorius, fibres have been measured which are much longer than the dimension above given.

Generally speaking the fibres neither divide nor anastomose; but this rule is not without exception. In the tongue of the frog the muscular fibres (fig. 114) as they approach the surface divide into numerous branches, by which they are attached to the under surface of the mucous membrane. The same thing has also been seen in the tongue of man and various animals: and the fibres of the facial muscles of mammals divide in a similar manner where they fix themselves to the skin (Busk and Huxley).

Fig. 115.

Fig. 115.—MUSCULAR FIBRE OF FISH. SUBSTANCE OF FIBRE RUPTURED SO AS TO EXHIBIT SARCOLEMMA. (After Bowman.)

Fig. 116.

Fig. 116.—SARCOLEMMA OF MAMMALIAN MUSCLE, HIGHLY MAGNIFIED (E.A.S.).

The fibre is represented at a place where the muscular substance has become ruptured and has shrunk away, leaving the sarcolemma (with a nucleus adhering to it) clear. The fibre had been treated with serum acidulated with acetic acid.

Structure of the fibres; sarcolemma.—A muscular fibre may be said to consist of a soft contractile substance inclosed in a tubular sheath. The latter is named the *sarcolemma* or *myolemma*. It consists of transparent and apparently homogeneous membrane agreeing in physical and for the most part in chemical characters with elastic tissue, and, being comparatively tough, will sometimes remain entire when the included fibrils are ruptured by stretching the fibre, as represented in fig. 115. It is especially well seen in fish and amphibia, for in these it is thicker and stronger than in

mammalian muscle, in which it is more difficult to render evident but nevertheless always exists (fig. 116). Nuclei are found on the inner surface of the sarcolemma, but these belong rather to the contractile substance than to the inclosing membrane, and will be afterwards more fully described.

Contractile substance.—When viewed by transmitted light with a sufficiently high power of the microscope, the fibres, which are then clear and pellucid in aspect, appear marked with parallel stripes or bands alternately light and dark passing across them directly or somewhat obliquely with great regularity (fig. 117), and this not only at the surface but, as may be seen by altering the focus of the microscope, throughout its substance also. The dark and light bands are nearly of equal breadth, and when the fibre is much extended, a fine dark dotted line becomes visible in the middle of the light band, and dividing it into two. About eight or nine dark and as many light bands may be counted in the length of $\frac{1}{1000}$ of an inch, which would give about $\frac{1}{2000}$ inch as the breadth of each. But whilst this may be assigned as their usual breadth in human muscle, they are in different parts found to be much narrower, so that not unfrequently there are twice as many in the space mentioned. This closer approximation may generally be noticed in thicker and apparently contracted parts of the fibre. The cross-striped appearance, which is very characteristic, is found in all the voluntary muscles; but it is not altogether confined to them, for it is seen in the fibres of the heart, which is a strictly involuntary organ: striped fibres are also found in the pharynx and upper part of the gullet, in the muscles of the internal ear, and those of the urethra, parts which are not under the direct control of the will.

Fig. 117.

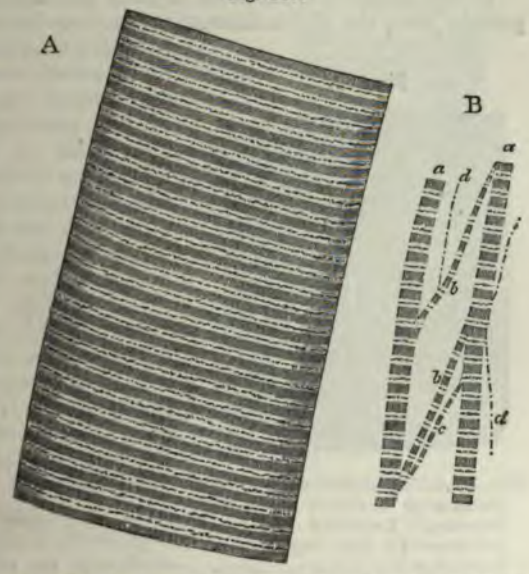

Fig. 117.—A, PORTION OF A MEDIUM-SIZED HUMAN MUSCULAR FIBRE, MAGNIFIED NEARLY 800 DIAMETERS (Sharpey).

B, SEPARATED PORTION OF A FIBRE, EQUALLY MAGNIFIED. *a*, *a*, larger, and *b*, *b*, smaller collections of fibrils; *c*, still smaller; *d*, *d*, the smallest which could be detached.

Fibrils; disks; sarcous elements.—The proper substance of the fibre presents, besides the transverse bands, an appearance of longitudinal striation, which is the better marked where the transverse striation is less distinct. On separating the fibre with needles, especially after hardening in alcohol, it may be broken up longitudinally into the so-

called *fibrils*, which, when of a certain fineness, appear to consist of a row of dark quadrangular particles (fig. 117, B, *b*), with bright intervals, the latter traversed by a dark dotted line, *c*, when the fibre is sufficiently extended. These rows of quadrangular particles which are sometimes taken to represent the sarcous elements of Bowman (see below) may, however, be further separated, as was shown by Sharpey, and the finest filaments so obtainable present the appearance of lines regularly broken at short distances (*d*). Each such thread may perhaps be looked upon as an ultimate fibril. It must, however, be borne in mind that the fibre is not wholly composed of these fibrils, but that there is in addition a not inconsiderable amount of intermediate substance.

Under other circumstances, as after the action of dilute acids or of gastric juice, the fibres show a tendency to cleave across in a direction parallel to the bands, and even to break up into transverse plates or disks, which are formed by the lateral cohesion of the particles of adjacent fibrils. To make up such a disk, therefore, every fibril contributes a particle, which separates from those of its own fibril, but coheres with its neighbours on each side, and this with perfect regularity. From a consideration of these facts, therefore, Bowman was led to conclude the subdivision of a fibre into fibrillæ to be merely a phenomenon of the same kind as the separation into disks, only of more common occurrence, the cleavage in the latter case taking place longitudinally instead of transversely: accordingly, he came to the conclusion that the fibrillæ have no existence as such in the fibre, any more than the disks; but that both the one and the other owe their origin to the regular arrangement of the particles of the fibre (sarcous elements) longitudinally and transversely, whereby, on the application of a severing force, it cleaves in the one or in the other direction into regular segments.

Fig. 118.

Fig. 118.—TRANSVERSE SECTION OF PORTION OF MUSCULAR FIBRE OF LOBSTER. EXAMINED IN SALT SOLUTION (½ PER CENT.) AND MAGNIFIED 400 DIAMETERS (Kölliker).

The polygonal areas of Cohnheim are seen, and among them two or three irregular nuclei.

If a transverse section of a muscular fibre is examined with a high power, it often appears to be marked out into small polygonal areas (Cohnheim) separated by clear lines (fig. 118). These areas are usually regarded as representing sections of the fibrillæ, but they would seem rather to correspond to groupings of the ultimate fibrillæ, for the fibrillæ are much smaller than the areas (compare fig. 117, B, *d*). Moreover, the areas may often be seen to have a punctated appearance, as if made up of the sections of a number of smaller elements. It must not be forgotten that the separation of a muscular fibre into disks or into fibrillæ is only possible after the coagulation of the muscle-plasma, or the action of re-agents upon it.

If perfectly fresh mammalian muscle is examined very carefully with

wers, especially if the upper surface of the fibre is focussed, the esent the appearance shown in fig. 119, which on a smaller scale that of insect muscle, as shown in fig. 120. By varying the is appearance and that exhibited in fig. 117 may often be obtained ely, showing that optical conditions have much to do with the ve effects produced by the examination of this tissue.

cle-nuclei or muscle-corpuscles.—In connexion with the cross- substance a number of clear oval nuclei are found in the fibres. malian muscles they lie upon the inner surface of the sarcolemma 6, 119), but in frogs they are distributed through the substance ibre. Associated with and surrounding ere is sometimes, but not always, to be certain amount of granular protoplasm, nades off at the margins into the contrac- tance of the fibre. Both substances are from the original formative protoplasm embryonic cells which compose the Max Schultze). In the unaltered con- e nuclei are not easily seen, but they may conspicuous by the addition of acetic hey contain a network of nucleoplasm, in ne or two nucleoli are generally visible.

Fig. 119.

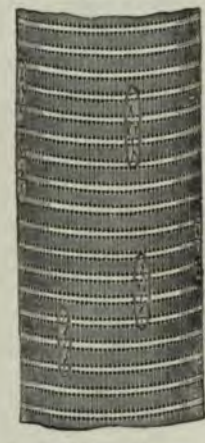

Fig. 119. — MUSCULAR FIBRE OF A MAMMAL EXAMINED FRESH IN SERUM, HIGHLY MAGNIFIED. (E. A. S.)

The nuclei are seen on the flat at the surface of the fibre, and in profile at the edges.

rabbit and hare, as especially pointed out by certain of the voluntary muscles present dif- in appearance and mode of action from the rest. ile most of the voluntary muscles have a pale d contract energetically when stimulated, some the semi-tendinosus and the soleus in the ab, are at once distinguished by their deeper well as by their slow and prolonged con- when stimulated. When subjected to micro- examination it is found that in the red muscle s are more distinctly striated longitudinally transverse striæ are much more irregular al. The nuclei also are far more numerous not confined to the inner surface of the sarco- ut occur here and there in the thickness of as well. There is also a difference in the pply of the two kinds of muscle, to be after- nded to.

ilar difference between red and pale muscles lso seen in the Rays amongst fishes. In other animals the distinction is d as regards whole muscles although it may affect individual fibres of a This is especially the case, according to Klein, in the diaphragm, in many of the fibres there are numerous nuclei, and these are embedded lasm, which forms an almost continuous layer underneath the sarcolemma. iliarities in question seem to be dependent upon the amount of work muscle is habitually called upon to perform, and are probably connected nutrition and renovation of the muscle-substance (Meyer).

he difficulty of making out all the details of structure of the mammalian rising from the extreme delicacy of its component elements and their to changes, histologists have availed themselves of the facilities afforded uscular fibres of insects, in which the elements are relatively large, and the fibres can be readily isolated in an unaltered and still contractile

ce of one of the muscles which move the legs be removed from the

abdomen of one of the common water-beetles (Dytiscus marginalis), and while still fresh and living be examined, either in the blood of the insect or without the addition of any fluid, with a high power of the microscope, most of the fibres are seen to present, like mammalian muscle, the appearance of alternate dim and bright transverse bands. Each dim band is traversed by a series of fine lines set side by side, which refract the light more strongly than the rest of the muscular substance, and hence appear somewhat darker (fig. 120, *d*). Crossing the fibre in the middle of each of the bright stripes a double row of dots (*c*) is apparent: and on close inspection it may be seen that each line of the dim stripe is traceable at either end into one of the dots of the bright stripe; as if the dots were the enlarged ends of the lines. Thus the structure which the lines and dots indicate, belongs both to the dim and to the clear bands, the interval between the double row of dots corresponding to the middle of the clear band. In an optical transverse section of a fibre it may easily be seen that the lines in question represent rod-shaped structures, and not partitions in the fibre, as some have supposed, for they appear in cross-section as minute dots separated by clear interstitial

Fig. 120.

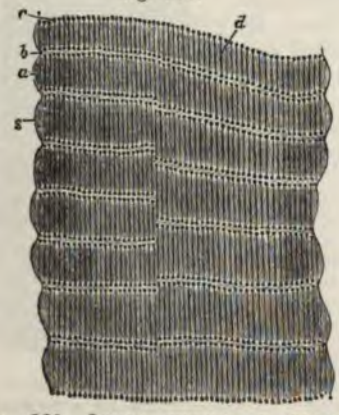

Fig. 120.—Living muscle of water-beetle (dytiscus marginalis). Highly magnified. (E. A. S.)

s, sarcolemma; *a*, dim stripe; *b*, bright stripe; *c*, row of dots in bright stripe, which seem to be the enlarged ends of rod-shaped particles, *d*.

Fig. 121.

Fig. 121.—Transverse section of a muscular fibre of water-beetle. Highly magnified.

s, sarcolemma.

substance (fig. 121). The light and dark stripes are not sharply marked off from one another, nor is their line of junction an even one, for, on careful inspection, it is seen to be crenated, each crenation corresponding to a dot, the appearance being like that which would be produced if there were a clear halo around each of the dots, and as if the successive haloes had blended together to form the bright band.

Now it is familiar to microscopical observers that whenever any strongly refracting particle, such as a micrococcus or a minute oil globule, is examined in water with a high power of the microscope, it appears surrounded by a bright halo due to its refracting effect upon the light, and perhaps partly to the reflexion from its surface. And a row of micrococci seems to lie in a bright line due to the blending of the successive haloes formed around each one. If we assume, then, as the appearance of the transverse section would seem to justify us in doing, that the lines shown in fig. 120 are the expression of rod-like bodies with knobbed ends (muscle-rods), which ends correspond in situation with the bright striæ, such a view would completely account for the brightness of the latter, and has, moreover, the advantage that it offers a simple explanation of the appearance presented by the

dissociated, even in the fresh condition, into very small fibres or fibrils which are collected into bundles surrounded by the ramifications of the air-tubes or tracheæ. Each separated fibre, if sufficiently extended (fig. 123, C), is composed of alternate dark and light disks, and in the middle of the light disk there is seen a fine sharply marked intermediate dark line *m*, but the appearances vary much according to the state of extension of the fibril (see fig. 123). No rod-like structure had, until quite recently, been detected in these fibrils of the wing-muscles, and this was believed to constitute an essential distinction between them and the ordinary muscles, but with the aid of improved objectives Wagener has been able to detect fine longitudinal elements in the former also.

Fig. 123.

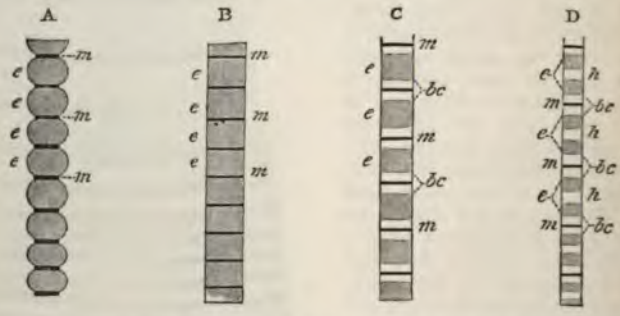

Fig. 123.—Fibres of the wing-muscles of an insect (after Ranvier).

The fibres are in different conditions of extension, from A least extended, to D most extended. *e*, *e*, chief substance of the fibre; *m*, *m*, intermediate lines or disks; the light bands, *bc*, on either side of these only come to view when the fibre is sufficiently stretched (C); with further extension (D), the middle of the dark band appears lighter, *h*.

Brücke's observations upon the appearances of muscle under polarized light.—It was noticed by Boeck that, like some of the other tissues, muscle is doubly refracting (anisotropous). Brücke however was the first to point out that the fibre is not composed entirely of anisotropous substance, but that there is in addition a certain amount of singly refracting or isotropous material. Since the important researches of the last-named author form the basis of our knowledge of this subject, a short account will be given of them here.

In the first place Brücke distinguishes between the appearances presented by living muscle examined in its own plasma and those of dead and prepared muscle. In dead muscle, although a considerable variation is noticeable in the relative amount of anisotropous and isotropous substance, nevertheless the two substances invariably take the form of alternating bands, dark and light, crossing the fibre and apparently corresponding in position with the light and dark stripes of the fibre as seen under ordinary light.

It is quite otherwise with living muscle. In this almost the whole of the fibre looks doubly refractile, the isotropous substance occurring only as fine transverse lines, or as rows of rhomboid dots which are united to one another across the anisotropous substance by fine longitudinal lines. This account is illustrated by fig. 124, which is copied from Brücke. Now if this figure be compared with fig. 120, or with the parts marked R of fig. 122, which represent the living muscle of a water-beetle under ordinary light, it is obvious that the rhomboid points and longitudinal lines of the one correspond to the muscle-rods of the other. The substance of the rods there-

The next prominent writer upon the subject was Merkel (1872), who described the transverse membranes of Krause as being double, and who corroborated Hensen's description of the existence of a lighter line or disk in the middle of the dark stria. But the most important difference in Merkel's account occurs in his description of the process of contraction. According to him, the anisotropous substance of the dark stria first of all becomes diffused over the whole muscle-compartment, so that the fibre acquires a homogeneous appearance, and then at a later stage becomes accumulated against the transverse membranes, while the isotropous substance on the other hand is accumulated on either side of Hensen's disk, so that the position of the two substances is thus reversed.

Fig. 125.

Fig. 125.—Diagrammatic representation of a muscle-case under a very high magnifying power (W. Krause).

A, at rest; B, condition in contraction, former view; C, condition in contraction, present view. *an*, muscle-prism, consisting of a bundle of muscle-rods; *is*, fluid isotropous substance.

Merkel was closely followed by Engelmann (1873), according to whose description, a muscular fibre consists of a succession of superimposed parts or compartments, which are partitioned off from one another by thin disks or membranes—Krause's membranes or intermediate disks (fig. 126, *a a*)—which may occasionally be double. Within each compartment is a series of disks, varying in their refractive power and in their action upon polarized light, as follows:—Next to an intermediate disk comes a comparatively narrow layer of isotropous clear substance, then a thin disk of dim substance, which is feebly anisotropous, and is distinguished as the accessory disk, (*b*); this is followed by a narrow layer of clear isotropous substance; then comes a broad disk of anisotropous substance (principal disk, *c*), occupying the greater portion of the muscle-compartment, and sometimes bisected by a narrow pale disk, which lies exactly in the middle of the compartment, and is distinguished as the middle disk or disk of Hensen (not seen in the figure). Beyond the broad anisotropous disk come in inverse succession isotropous substance, accessory disk, and intermediate disk, and so on in the next compartment.

When contraction is about to supervene in any part of a muscular fibre, the changes, which according to Engelmann may be observed, are the following:—While the intermediate disks approach one another, the successive disks within each muscle-compartment become less distinct, and the fibre loses in great measure at the part in question (that namely in which the contraction is beginning), its striated appearance. The stage in question is accordingly termed by Engelmann the homogeneous stage (fig. 126, H.). As the contraction progresses, transverse striæ again make their appearance, in consequence of the gradual darkening of the accessory disks and concomitant clearing up of the principal disk, so that now each intermediate disk with its juxtaposed accessory disks forms a distinct dark isotropous band, these alternating with the narrowed and now bright-looking principal disks of anisotropous substance (fig. 126, C.) The reversal of the striæ in contracting muscle is ascribed by Engelmann wholly to changes in refrangibility in the several substances which compose the disks of the muscle-compartment accompanied by an increase in the volume of the principal disk at the expense of the isotropous substance.

With regard to the above account of the changes which occur during contraction, it should be mentioned that it is not founded upon the observation of the contractile change as it may be seen to occur in the living muscle, but on the examination of the so-called "fixed waves of contraction," which are seen in fibres of muscles obtained from insects which have been killed by being placed in osmic acid or alcohol. On such fibres it often happens that

one or more swellings occur upon the otherwise extended fibre, and these swellings are assumed to be contractile waves, which have been fixed during their passage along the fibre by the sudden influx of the reagent, it being taken for granted that the reagents in question fix the living muscular fibres in exactly the same condition as at the time of immersion. But this assumption is not borne out by the facts of the case. For if the living muscular tissue of an insect is being observed under the microscope, and a drop of osmic acid or of alcohol is allowed to come into contact with it, the whole fibre if free to contract at once does so, and remains contracted. Moreover, as the reagent penetrates the substance of a fibre, the appearance of the latter becomes profoundly modified in place of remaining unaltered as asserted by Engelmann. If the ends of the muscle are fixed so that it is not free to contract, the general shortening of the fibre and the approximation of the discs may not occur except here and there, and at these places the swellings known as fixed waves of contraction manifest themselves, but it by no means follows that in the intermediate parts the fibre, although extended, is not, so far as regards the arrangement of its elements, in the condition that ordinarily accompanies contraction. The homogeneous appearance at the rise and fall of the "fixed wave," may be accounted for if we consider that the longitudinal elements are liable to become shifted somewhat by the shortening of a neighbouring part of the fibre, for it is well known that mechanical shifting of the elements of a fibre causes a disappearance of the transverse striation.

Fig. 126.

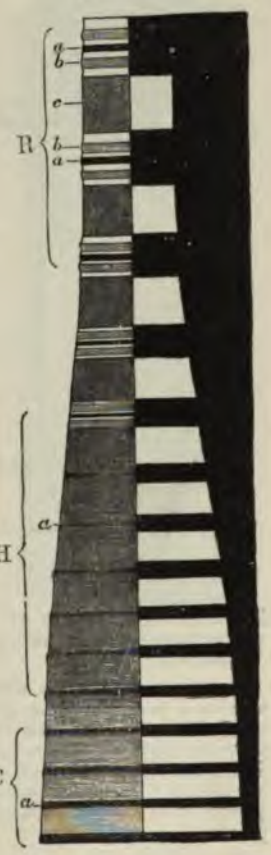

Fig. 126.—Muscular fibre of an insect, exhibiting a part of one of the so-called "fixed waves of contraction" (from Engelmann).

The right half of the figure shows the effect produced by the same fibre when examined under polarised light, the principal disks then appearing light on the dark field caused by the crossed Nichols' prisms.

R, part at rest, or at least extended; H, homogeneous part; C, contracted part. *a*, intermediate disk; *b*, accessory disk; *c*, principal disk.

Ranvier (1880) reverts to a view of muscle-structure which is similar to that of Krause, but gives an entirely different account of the changes which accompany contraction.

Whatever may be the interpretation put upon the appearances exhibited by muscle, there is little doubt that the contractile phenomena are of essentially the same nature in voluntary muscle as in involuntary muscle, and even as in cilia, and in the movements of simple protoplasmic cells. Both the contraction of muscle and the contraction of protoplasm are dependent upon the maintenance of nutrition, and are influenced similarly by external conditions. The only striking point of difference, apart from the relative quickness or slowness with which stimuli are responded to, lies in the fact that in muscle, whether voluntary or involuntary, the contraction is confined to one dimension, whereas ordinary protoplasm is capable of contracting in any direction. That in the living condition the substance of a muscular fibre is, like protoplasm, of a semi-fluid nature, was proved by the

oft-quoted observation of Kühne (repeated by Eberth), who observed a minute parasitic worm moving in the interior of a living muscular fibre of the frog, and noticed that the transverse striæ and other markings in the fibre which were displaced by the movements of the worm, closed in again behind it, reassuming their proper order and former position.

Mode of Attachment of Muscular Fibres: Ending of Muscle in Tendon.—When a muscle ends in a tendon it is found that the muscular fibres either run in the same direction as the tendon-bundles or join with the tendon at an acute angle. In the former case the tendon becomes subdivided, either gradually or suddenly, into as many small bundles as there are fibres in the end of the muscle, and it often seems at first sight as if the tendon-fibres were directly continued into the muscular substance. In reality, however, the fibres of each tendon-bundle end abruptly on reaching the rounded or obliquely truncated extremity of a muscular fibre (fig. 127), and are so intimately united to the prolongation of sarcolemma which covers the extremity, as to render the separation between the two difficult if not impossible (Ranvier). The muscular substance, on the other hand, may readily be caused to retract from the sarcolemma at this point. The areolar tissue which lies between the tendon-bundles, passes between the ends of the muscular fibres and is gradually lost in the interstitial connective tissue of the muscle.

Fig. 127.

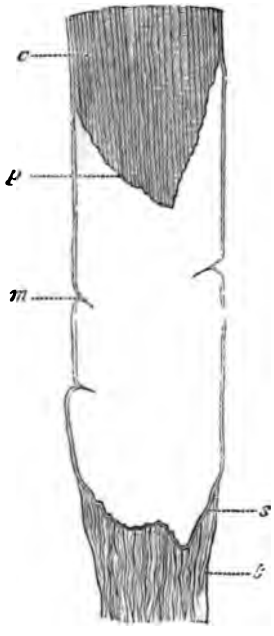

Fig. 127.—Termination of a muscular fibre in tendon (Ranvier).

m, sarcolemma; *s*, the same membrane passing over the end of the fibre; *p*, extremity of muscular substance, *c*, retracted from the lower end of the sarcolemma-tube; *t*, tendon-bundle passing to be fixed to the sarcolemma.

When the direction of the muscular fibres is oblique to that of the tendon, the connection takes place in a similar way to that above described, but the small tendon bundles are given off laterally along the course of the tendon, which in these cases is generally prolonged into or over the muscle.

When the muscular fibres divide, each branch of the fibre is described as being directly continuous with a tendon-bundle, or connective tissue bundle, without the intervention of sarcolemma, but it is not improbable that renewed careful investigation might, in this case also, disclose the existence of a thin prolongation of sarcolemma over the divisions.

Blood-vessels.—The blood-vessels of the muscular tissue are very abundant, so that, when they are successfully filled with coloured injection, the fleshy part of the muscle contrasts strongly with its tendons. The arteries, accompanied by their associate veins, enter the muscle at various points, and divide into branches: these pass among the fasciculi, crossing over them, and dividing more and more as they get

en the finer divisions of the muscle; at length, penetrating nallest fasciculi, they end in capillary vessels, which run between bres. The vessels are supported in their progress by the sub-ons of the sheath of the muscle, to which also they supply ries. The capillaries destined for the proper tissue of the muscle tremely small; they form among the fibres a fine net-work, with oblong meshes (fig. 128), which are stretched out in the direction fibres; in other words, they consist of longitudinal and transverse , the former running parallel with the muscular fibres, and lying angular intervals between them,—the latter, which are much r, crossing between the longitudinal and passing over or under the in-ing fibres.

Fig. 128.

Fig. 128.—CAPILLARY VESSELS OF MUSCLE, MODERATELY MAGNIFIED. (E.A.S.)

e deeper coloured muscular fibres of those which, like the rabbit, possess two kinds ntary muscles, the transverse loops of illary net-work are dilated far beyond of the ordinary capillaries.

number of capillaries in a given space of le, or their degree of closeness is partly ed by the size of the fibres; and accord-n the muscles of different animals it is hat, when the fibres are small, the vessels merous and form a close network, and *rsâ:* in other words, the smaller the the greater is the quantity of blood sup-o the same bulk of muscle. In confor-with this, we see that in birds and alia, in which the process of nutrition e, and where the rapid change requires ous supply of material, the muscular are much smaller and the vessels more ns than in cold-blooded animals, in the opposite conditions prevail.

mphatics.—So far as is known are no lymphatic vessels in the ary muscles, although there is an ant supply in their connective tissue s and tendons, and the lymphatic here would seem, as pointed out by ig and Schweigger-Seidel, to serve rpose of collecting and conveying away the lymph from the muscular nce. How the fluid reaches the lymphatic vessels of the sheath is rtainly known: it may be by the medium of the intercommuni-spaces of the connective tissue which penetrates between the li and fibres of the muscle.

rves.—The nerves of a voluntary muscle are of considerable size. branches pass between the fasciculi, and repeatedly unite with ther in form of a plexus, which is for the most part confined to l part of the length of the muscle, or muscular division in which . From one or more of such primary plexuses, nervous twigs d, and form finer plexuses composed of slender bundles, each con-g not more than two or three dark-bordered nerve-fibres, whence fibres pass off between the muscular fibres and divide into

branches which are finally distributed to the tissue. The mode of final distribution will be described with the general anatomy of the nerves.

Nerves of small size accompany the branches of blood-vessels within muscles; though destined for the vessels, these nerves are said sometimes to communicate with the proper muscular plexuses.

DEVELOPMENT OF VOLUNTARY MUSCULAR TISSUE.

Most of the voluntary muscles of the body are developed from a series of portions of mesoderm which are early set aside for this purpose in the embryo and are termed the muscle-plates. The cells which compose these are similar in most respects to those in the remainder of the mesoderm, but when the muscular fibres are about to be formed the cells become elongated, and their nuclei multiplied so that each cell is converted into a long multi-nucleated protoplasmic

Fig. 129.

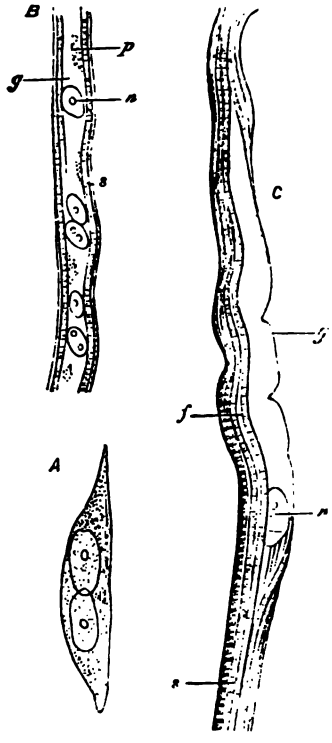

Fig. 129. — DEVELOPING MUSCULAR FIBRES. HIGHLY MAGNIFIED.

A, elongated cell with two nuclei and a striation beginning down one side of the cell (from fœtal sheep, Wilson Fox).

B, from fœtus of 2 months; *p*, granular protoplasm; *g*, glycogenous substance; *n*, nucleus; *s*, commencing sarcolemma, with striated muscular substance developing immediately beneath it.

C, from fœtus of 3 months, displayed so as to show the contractile substance collected at one side of the fibre, and partially enclosing the unaltered substance of the fibre, *g*; *f*, fibrils. B and C from Ranvier.

fibre. At first the substance of the fibre is not striated but is merely granular in appearance, but presently it becomes longitudinally striated along one side (fig. 129, A), and about the same time a delicate membrane, the sarcolemma, may be discovered bounding the fibre. The longitudinal striation, which is the first indication of the proper muscular substance, extends along the whole length of the fibre, but at first as just intimated affects only a small part of its breadth, the rest being formed by a highly glycogenic protoplasm containing the nuclei. In due time, however, this conversion into the proper muscular substance, further shown by the appearance of cross striæ (fig. 129, B and C), proceeds through the whole thickness of the fibre, and the nuclei take up their permanent position underneath the sarcolemma.

Schwann considered each fibre to be formed by the linear coalescence of several cells; but the researches of Kölliker, Wilson Fox, and others, tend to establish the view, originally promulgated by Remak, that the fibres are produced as above described by the elongation of single cells, with differentiation of their contents and multiplication of their nuclei.

Growth.—The muscular fibres, after having acquired their characteristic form and structure, continue to increase in size till the time of birth, and thenceforward up to adult age. In a full-grown fœtus most of them measure twice, and some of them three or four times their size at the middle of fœtal life; and in the adult they are about five times as large as at birth. This increase in bulk of the individual fibres would, of course, so far account for the concomitant enlarge-

ent of the entire muscles. It is uncertain how far there may be a multiplication new formation of muscular fibres during the growth of a muscle.

Regeneration.—It is generally stated that after removal by the knife or by ease striated muscular tissue is not regenerated, but that any breach of continuity which may occur in a muscle is filled up by a growth of connective tissue. would appear, however, that the breach is eventually bridged across by muscular substance, the new muscular tissue in all probability being formed by the wth of the old muscular fibres into the connective tissue which unites the cut ds.

Nothing is certainly known about the actual process of waste and renewal ich must be continually occurring in so active a tissue as the one in question. s probable that in most cases the changes are molecular, and that the muscular es are never removed *in toto* by absorption. But the case may be otherwise some animals, as, for example, in frogs, which in the winter season have ay of their fibres destroyed by fatty degeneration. According to Beale and Wittich these are replaced by the development of new fibres from cells ch lie between the existing fibres, by a process analogous to the original elopment, but Weissmann and Kölliker state that the formation of new fibres take place by the splitting up of the old fibres along their whole length.

INVOLUNTARY MUSCLES.

The involuntary muscular tissue differs from the voluntary kind, not y in some of its physiological properties but also in its anatomical racters; for whilst in many parts it appears in the form of fibres, se, except in the heart and a few instances of less note, are unmarked the cross lines so characteristic of the striped fibres; moreover, the arent fibres are in reality made up of elongated contractile cells ented together by some kind of uniting medium. Microscopically kinds of involuntary muscular tissue are distinguished, viz. the *n* or *unstriped*, and the *cardiac* tissue; the latter may be regarded as rm of tissue intermediate between the cross-striated voluntary fibres the plain involuntary muscular tissue.

PLAIN OR UNSTRIPED MUSCULAR TISSUE.

his, as has just been remarked, is made up of cells, named *contile fibre-cells*, which were first distinguished as the true elements he tissue by Kölliker. The cells may form fibrous bundles, and ta, or may be less regularly arranged, and the tissue occurs either st pure or mixed with other tissues in varying proportion. The are of an elongated fusiform shape (figs. 130 and 131), usually ted at the ends. They are generally roundish or prismatic in sverse section, but are sometimes more flattened. The cells vary tly in length according to the part or organ in which they are found. e occur which are cleft or forked at one or both ends. Their tance is finely vacuolated and exhibits also a faint longitudinal llation. It is doubly refracting. Each cell has a nucleus (*a*, *a*), ly more than one, which is always elongated and either oval or rod-ed. Towards each end of the nucleus the substance of the cell lly contains a few distinct granules arranged in linear series.

he nucleus shows the usual structure, having an intranuclear net t (fig. 130, A). The involuntary fibre-cells can be shown to possess an edingly delicate homogeneous sheath or envelope (fig. 130, B), and like sarcolemma of voluntary muscular fibres, this sheath is apt to be kled when the fibre is contracted, so that an indistinct appearance of

striation may thus be produced. The cells are united by a small am of intercellular cementing substance which becomes stained by n of silver.

They are generally collected into larger and smaller fasciculi, whi many cases cross one another and interlace. The fasciculi are att at their ends by connective tissue to the membranous and firmer where they occur. In some cases the attachment of the plain mu cells takes place by means of elastic fibres which bifurcate at the e

Fig. 130. Fig. 131.

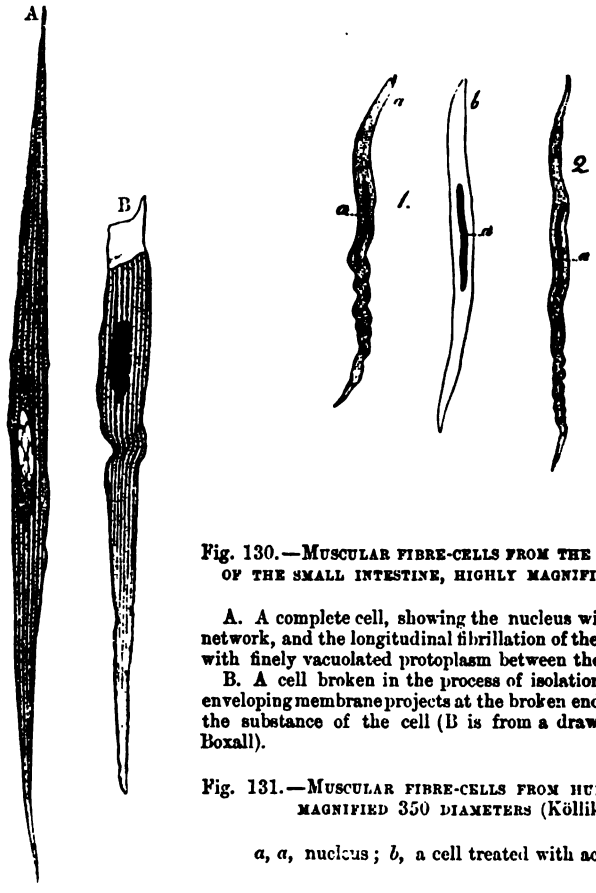

Fig. 130.—MUSCULAR FIBRE-CELLS FROM THE MUSCUL. OF THE SMALL INTESTINE, HIGHLY MAGNIFIED (E. .

A. A complete cell, showing the nucleus with intra network, and the longitudinal fibrillation of the cell-sul with finely vacuolated protoplasm between the fibrils.

B. A cell broken in the process of isolation; the enveloping membrane projects at the broken end a little the substance of the cell (B is from a drawing by Boxall).

Fig. 131.—MUSCULAR FIBRE-CELLS FROM HUMAN AR MAGNIFIED 350 DIAMETERS (Kölliker).

a, *a*, nucleus; *b*, a cell treated with acetic aci

the muscular cell. The two branches extend along either side o and are firmly attached to it. In other cases again, accordi Watney, the attachment may take place through the medium of c tive tissue corpuscles, the branches of which embrace the muscul in like manner.

Distribution.—The plain muscular tissue is for the most par posed in the coats of the membranous viscera. It is met with in the half of the gullet, the stomach, and the whole intestinal canal; t

muscles. They differ also from these in being made up of distinct quadrangular cells (fig. 133) joined end to end and often presenting a branched or forked appearance near one extremity (*c*). Each cell has a single clear

Fig. 134.

Fig. 134.—MUSCULAR FIBRES FROM THE HEART, MAGNIFIED, SHOWING THEIR CROSS STRIÆ, DIVISIONS, AND JUNCTIONS (Schweigger-Seidel).

The nuclei and cell-junctions are only represented on the right-hand side of the figure.

oval nucleus situate near the centre ; occasionally two nuclei are seen. The cell substance is striated longitudinally as well as transversely, its substance appearing to be composed of a number of parallel columns or fibrils, which on transverse section are seen as small polygonal areas. An investing membrane or sarcolemma has not hitherto been proved to exist on these fibres.

The muscular fibres of the heart freely divide and anastomose (fig. 134), the junctions with neighbouring fibres being effected by the medium of the cell-offsets above noticed.

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NERVOUS SYSTEM.

The nervous system consists of a *central part*, or rather a series of connected *central organs*, named the *cerebro-spinal axis*, or *cerebro-spinal centre;* and of the *nerves*, which have the form of cords connected by one extremity with the cerebro-spinal centre, and extending from thence through the body to the muscles, sensible parts, and other organs placed in functional relation with them. The nerves form the medium of communication between these distant parts and the centre. One class of nervous fibres, termed *afferent* or *centripetal*, conduct impressions towards the centre,—another, the *efferent* or *centrifugal*, carry motorial stimuli from the centre to the moving organs.

Besides the cerebro-spinal centre and the nervous cords, the nervous system comprehends also certain bodies named *ganglia*, which are connected with the nerves in various situations. These bodies, though of much smaller size and less complex nature than the brain, agree, in some respects, with that organ in their elementary structure, and to a certain extent also in their relation to the nervous fibres with which they are connected; and this correspondence becomes even more apparent in the nervous system of the lower members of the animal series.

The nerves are divided into the *cerebro-spinal*, and the *sympathetic* or *ganglionic* nerves. The former are distributed principally to the skin, the organs of the senses, and other parts endowed with manifest sensibility, and to muscles placed more or less under the control of the will. They are attached in pairs to the cerebro-spinal axis, and like the parts which they supply are, with few exceptions, remarkably symmetrical on the two sides of the body. The sympathetic or ganglionic nerves, on the other hand, are destined chiefly for the viscera and blood-vessels, of which the motions are involuntary, and the natural sensibility is obtuse. They differ also from the cerebro-spinal nerves in having generally a greyish or reddish colour, in their less symmetrical arrangement, and especially in the circumstance that the ganglia connected with them are much more numerous and more widely distributed. Branches of communication pass from the spinal and several of the cerebral nerves at a short distance from their roots, to join the sympathetic, and in these communications the two systems of nerves mutually give and receive nervous fibres; so that parts supplied by the sympathetic may be also in nervous connection with the cerebro-spinal centre.

The nervous system is made up of a substance proper and peculiar to it, with inclosing membranes, nutrient blood-vessels and supporting connective tissue. The *nervous substance* has been long distinguished into two kinds, obviously differing from each other in colour, and therefore named the *white*, and the *grey* or *cineritious*.

When subjected to the microscope, the nervous substance is seen to consist of two different structural elements, viz., *fibres* and *cells*. The fibres are found universally in the nervous cords, and they also constitute the greater part of the nervous centres: the cells on the other hand are confined in a great measure to the cerebro-spinal centre and the ganglia, and do not exist generally in the nerves properly so called, although they have been found at the terminations of some of the nerves of special sense, and also interposed here and there among the fibres of particular

nerves; they are contained in the grey portion of the brain and spinal cord, and in the ganglia.

NERVE-FIBRES.

Two kinds of nerve-fibres are met with in the body, differing from one another both in their microscopical character and in their more obvious aspect: those of the one kind have received the name of *white* fibres, on account of the appearance which they present when collected in considerable numbers, as in the nerve trunks or white matter of the nerve centres, the others being denominated *grey* fibres.

Fig. 135.

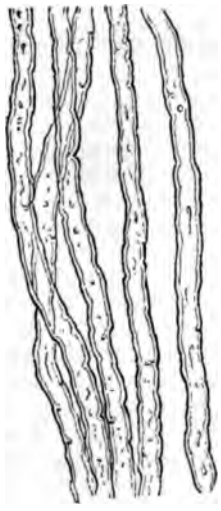


Fig. 136.

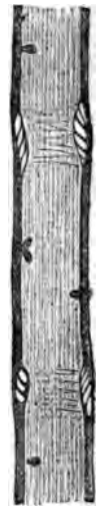


Fig. 135.—WHITE OR MEDULLATED NERVE-FIBRES, SHOWING THE SINUOUS OUTLINE AND DOUBLE CONTOURS (after Bidder and Volkmann).

Fig. 136.—A SMALL PART OF A MEDULLATED FIBRE HIGHLY MAGNIFIED (E. A. S.).

The fibre looks in optical section like a tube—hence the term tubular, formerly applied to these fibres. Two partial breaches of continuity are seen in the medullary sheath, which at these places exhibits a tendency to split into laminæ. The primitive sheath is here and there apparent outside the medullary sheath, and the delicate striæ which are visible in the middle of the fibre probably indicate the fibrillated axis-cylinder.

When examined with the microscope it is found that this difference of aspect depends upon the presence or absence of a peculiar sheath to the fibre, formed of a kind of fatty substance, this fatty or medullary substance, as it is termed, giving a dark double contour to the white fibres (when seen by transmitted light), which is altogether absent from those of the other kind. On account of this the white fibres are also known as the *dark-bordered* or *medullated* fibres, the grey fibres being termed in contradistinction the *pale* or *non-medullated* fibres, or from their discoverer, the *fibres of Remak*.

The **medullated nerve-fibres** form the white part of the brain, spinal cord, and nerves, and give it its white opaque aspect. Viewed singly under the microscope with transmitted light they are transparent, and, as before stated, are characterised by their well-defined even outline and, except the smallest, by their double contour, which gives them a tubular aspect.

Their size differs considerably even in the same nerve, but much more in different parts of the nervous system; some being as small as the $\frac{1}{15000}$th and others upwards of the $\frac{1}{1500}$th of an inch in diameter; moreover, the same fibre may change its size in different parts of its course, and it is generally smaller at its central and peripheral ends.

Fig. 137.

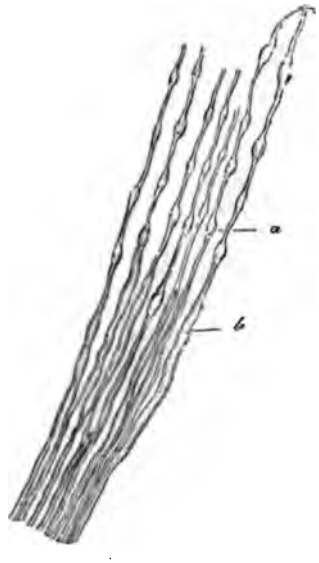


Fig. 138.

B.

Fig. 137.—Varicose medullated fibres from the root of a spinal nerve (from Valentin).

Fig. 138.—B. Diagram to show the parts of a medullated fibre, viz., 1, 1, *outer* or *primitive sheath* enclosing the doubly contoured *white substance* or *medullary sheath*. 2, a part where the white substance is interrupted the outer sheath remaining. 3, *axis cylinder* projecting beyond the broken end of the tube. 4, part of the contents of the tube escaped.

Many of the medullated nerve-fibres appear dilated or swollen out at short distances along their length, and contracted in the intervals between the dilated parts. These fibres, however, are naturally cylindrical like the rest, and continue so while they remain undisturbed in their place; and the varicose character is occasioned by pressure or traction during the manipulation, which causes the soft matter to accumulate at certain points, whilst it is drawn out and attenuated at others (fig. 137). The fibres in which this is most apt to occur are usually of small size, ranging from $\frac{1}{15000}$th to $\frac{1}{3000}$th of an inch in diameter; and when a

very small fibre is thus affected, the varicosities appear like a string of globules held together by a fine transparent thread.

The medullated fibres are composed for the most part of three distinct structures, viz., an axial fibre (the cylinder-axis of Purkinje), enclosed within two sheaths, one of these being the medullary sheath already mentioned, and the other a delicate membranous tube outside of all, termed the nucleated sheath of Schwann, the primitive sheath, or simply, the outer sheath. But there are medullated fibres in which the primitive sheath is absent, and other fibres and prolongations of fibres in which there is no sheath whatever to the axis-cylinder. But the latter is always present and is indeed the chief functional constituent of the nerve-fibre. The several parts of which the nerve-fibre is composed may now be described in detail.

Axis-Cylinder.—The essential part of every nerve-fibre, is a pale and somewhat indistinct strand, which runs in the axis of the fibre and is termed the *axis-band*, *axial-fibre*, or more commonly the *axis-cylinder* (fig. 138, 3 ; and 139, *c*). This essential part is usually inclosed,

Fig. 139.

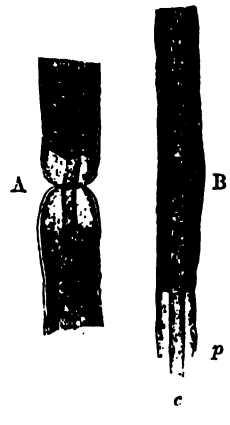


Fig. 140.

Fig. 139.—Two portions of medullated nerve fibres, after treatment with osmic acid, showing the axis-cylinder, and the medullary and primitive sheaths (Key and Retzius).

A. Node of Ranvier. B. Middle of an internode with nucleus.

c, axis-cylinder, projecting at the broken end ; *p*, primitive sheath within which the medullary sheath, which is stained dark by the osmic acid, is somewhat retracted.

Fig. 140.—Part of an axis-cylinder, highly magnified, showing the varicose fibrils composing it (Max Schultze).

as just mentioned, in one or more sheaths, but these are not always present, especially at the origin and termination of a nerve-fibre ; and even in the course of the fibre they may be interrupted at intervals. The central axis, on the other hand, undergoes no interruption along the

course of the nerve, from the nerve-centre to the peripheral dis-
on. It appears further to be clearly established that the axial
f a nerve is in nearly every case a direct prolongation of a branch
nerve-cell situated in one part or another of the nerve-centre.
herefore to be looked upon in the light of a far-extending cell
s; and the study of the development of the nerve-fibre affords a
confirmation of this view of its nature.

he fresh state, and under high powers of the microscope, the axis-
er presents an appearance of longitudinal striation, indicating a
r structure (fig. 140); and at the termination of the nerves it
often be seen to separate into a number of exquisitely fine
its or fibrils. These, the *primitive fibrillæ* of Max Schultze,
bedded in a homogeneous or finely-granular material, and may
ome reason be regarded as constituting the essential or con-
g part of the axis-cylinder, and therefore of the nerve: at least, it
itly happens that they form the only portion of the nerve-fibre
prolonged to the ultimate termination. The fibrils often exhibit
varicosities which are highly characteristic in appearance.

axis-cylinder appears to be invested with a very delicate
reless sheath.

s shown by Fromann that after treatment with nitrate of silver and
ent exposure to the light the axis-cylinder becomes stained in such a
as to exhibit a distinct cross-striated aspect, but it is not known
r this depends upon any structural feature of the fibre or not.

not always easy to distinguish the axis-cylinder in the medullated fibres
hey are examined in the fresh condition, but it can generally be made
t by staining the nerve with carmine or hæmatoxylin. In a transverse
of a nerve thus stained the axis-cylinders appear in the form of round
oloured dots in the centre of the fibres.

ullary Sheath.—The substance of the medullary sheath (which
med the white substance by Schwann on account of its presence
he chief cause of the whiteness of the nerves), undergoes peculiar
s on exposure of the nerve to the action of water and other fluids,
; the outline of the fibre is often rendered uneven; round and
ar spots appear at various points, the medullary sheath acquiring
ally a confusedly curdled aspect.

thickness of this sheath varies within wide limits, and indeed this
hief cause of the variation in size of the medullated nerve-fibres,
h the axis-cylinder may also vary in diameter to a considerable

In some fibres, the medullary substance forms an exceedingly
yer, so as to be scarcely distinguishable except by the darker
which it imparts to the fibre, or it may only occur in parts, these
ting irregularly with other parts in which there is a complete
of white substance. Such fibres, which are very common in
arts of the sympathetic system (fig. 152, *m*, *m*), may be regarded
itional between the white and the grey fibres.

s and internodes of Ranvier.—It was shown by Ranvier, that
nstantly occur in the peripheral medullated nerve-fibres breaks
continuity of the white substance, which succeed one another
lar intervals along the course of the nerves; and give the
the appearance of being constricted at these places. The

constrictions or *nodes of Ranvier*, as they may conveniently be term[illegible] divide the fibre into a series of *internodes* of nearly equal leng[illegible] The segmentation is readily made apparent by the action of [illegible]

Fig. 141.

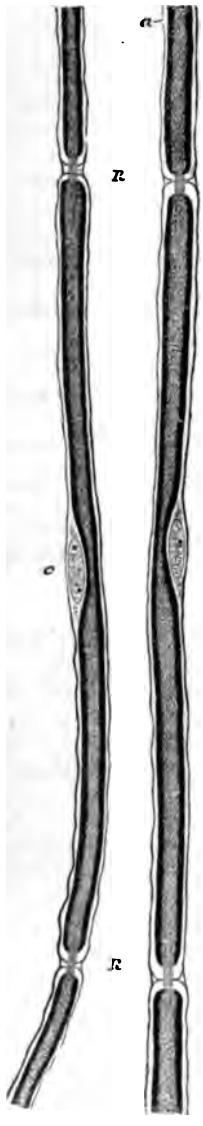


Fig. 141.—PORTIONS OF TWO NERVE-FIBRES STAINED [illegible] OSMIC ACID (FROM A YOUNG RABBIT). 425 DIAM[illegible] (E. A. S.).

R, R. Nodes of Ranvier, with axis-cylinder passing through. *a*, Primitive sheath of the nerve. *c*, Opposite the middle of the segment indicates the nucleus and protoplasm lying between the primitive sheath and the medullary sheath. In A the nodes are wider, and the intersegmental substance more apparent than in B. (From a drawing by Mr. J. E. Neale.)

solution of osmic acid, which leaves the nodes (fig. 141, R, R; fig. 142, E) almost colourless, while the medullary sheath, or white substance of Schwann, becomes stained of an inky black colour.

The white substance of the medullary sheath is often found to have shrunk somewhat in the neighbourhood of a node (fig. 139, A), and it can then be seen that there is present, in addition to it, a clear or finely granular stroma, which has become evident in consequence of retraction of the fatty substance which normally pervaded it.

The outer membranous sheath of the fibre appears to be continued over the nodes, for when a medullated fibre is examined in water and the substance of the medullary sheath exudes from the cut ends of the nerve-fibres, it is found that the place of that which thus escapes is taken by the white substance from the next internode; and this substance may be seen to flow past the constrictions of Ranvier without escaping at those points. Outside the primitive sheath the internodes are united by a disc of cementing substance—the "constricting band" of Ranvier — which, like intercellular substance elsewhere, becomes stained by nitrate of silver. The last-named reagent stains also the axis-cylinder in the neighbourhood of the node, so that the fibres after this treatment appear marked with little crosses (fig. 151); the transverse limb of the cross being due to the ring of intersegmental substance, the longitudinal to the axis-cylinder. Many other fluids stain the axis-cylinder at the nodes only, being prevented from reaching it elsewhere owing to the presence of the fatty matter in the surrounding medullary sheath.

Engelmann argues in favour of a discontinuity of the axis-cylinder (as well as of the medullary sheath) at the nodes of Ranvier, basing his argument partly on the immediate degeneration which results when a nerve-fibre is cut, partly on appearances obtained after a

thod of treatment with nitrate of silver, the dark deposit characinter-cellular substance traversing, according to his account, the

MEDULLATED NERVE-FIBRE TREATED WITH OSMIC ACID (Key and Retzius.) Fig. 142.

Ranvier (E) and a nucleus (K) is represented. The medullary ars broken up into a number of segments with conical or d ends fitting into one another.

f the axis-cylinder at the nodes. But such a view would stronger evidence than has yet been brought forward n be accepted, for it is opposed to the best ascertained regard to the development and regeneration of the axis-

middle of each internode an oval nucleus lies in the medullary sheath (figs. 139, B, 141, *c*, these nuclei will be described with the primitive

ry segments.—Other breaks of continuity are seen in ary sheath (fig. 136) which are of an entirely different a the nodes of Ranvier; indeed it is somewhat uncertain y correspond to a pre-existent structure in the fibre. In e of their presence the medullary sheath almost conears as if made up of a number of small cylindrical ith either conical or funnel-shaped ends which fit in with r in the alternate segments (fig. 142), and the parts in ave since been frequently described as integral conf the medullary sheath (Lantermann, Schmidt and is easy to convince oneself of the reality of the appearmentioned, but it is far less easy to be certain that t artificial productions. Against the view of their exthe natural condition it is to be noted that they are ariable in number and in size in a given length, even e nerve-fibre, that they appear to become increased in the nerve-fibre have been subjected to much manipulahey have no constant relation, so far as can be made other parts of the medullated fibre, and that, according mony of several careful observers, they are not to be seen ve-fibres of the living animal, unless these have been o an abnormal amount of traction or other mechanical is last assertion is denied, however, by others, who ie pre-existence of the medullary segments, and describe he oblique clefts which separate them as definite parts of

and reticular structures in the medullary sheath.—wn by McCarthy that after a nerve has been hardened ate of ammonium (picric acid is still better adapted for the e medullary sheath appears pervaded with minute rodures which pass radially between the axis-cylinder and ve sheath in such a manner as to give the cross-section fibre the appearance of a wheel. The rods stain with d hæmatoxylin, which do not colour the fatty substance ullary sheath. In nerves stained with osmic acid (in e structures were first detected by Lantermann) they are ily seen, in consequence of the dark colouration of the nce in which they are embedded. The rods are probably t from one another, but in reality united laterally so

as to form a close network, for if the nerve be first placed in strong alcohol and then subjected to the action of staining fluids it will be found that the rod-like structures are no longer visible but the medullary sheath appears pervaded instead by a finely reticular structure. The network thus obtained is considered by Kühne and Ewald, who first drew attention to it, to be chemically of a horny nature, on account of the resistance it offers to reagents, and especially to digestive ferments; and they further describe it as continuous with two exceedingly delicate membranes of a similar nature one immediately investing the axis-cylinder and the other lining the primitive sheath. Ranvier on the other hand describes the medullary sheath as bounded both towards the axis-cylinder and towards the primitive sheath by fine layers of protoplasm, and he regards these as being connected with one another by protoplasmic septa, which lie in the intervals between the conico-cylindrical segments of the medullary sheath.

It will be seen from the above that there is still much diversity of opinion with regard to the minute structure of the medullary sheath of the nerves. As to its chemical composition the white substance or *myelin* consists chiefly of protagon (or of its derivatives lecithin and neurin) together with cholesterin and one or two other substances in less amount. When escaped from the nerve-fibres it forms drops either rounded or irregular in shape, which always show the double contour which is so characteristic of the medullated nerve-fibres, the appearance being due to the peculiar manner in which myelin refracts the light. In contact with water it combines with that fluid, and as a result of the imbibition the myelin-drops undergo a considerable increase in bulk, accompanied by remarkable changes of form, often growing out into tube-like filaments for a considerable distance into the fluid. In this behaviour myelin is not peculiar but resembles certain other substances of a fatty and resinous nature.

Sheath of Schwann, Outer or **Primitive Sheath.**—The nucleated sheath of Schwann forms the outermost covering of the white nerve-fibres. It presents the appearance of a delicate homogeneous membrane with nuclei disposed at intervals along its inner surface. As already mentioned these nuclei bear a definite relation to the constrictions or nodes of Ranvier, for they lie about midway between the nodes, only one nucleus being found in each internode (fig. 141). The nuclei are oval and sometimes flattened, they usually lie in a depression of the medullary sheath, and at each end of the nucleus, especially in young nerves, there is a small amount of granular protoplasm which may spread for a short distance between the primitive and the medullary sheath. The primitive sheath turns in at the nodes and closely surrounds the axis-cylinder as this passes from one segment to the other.

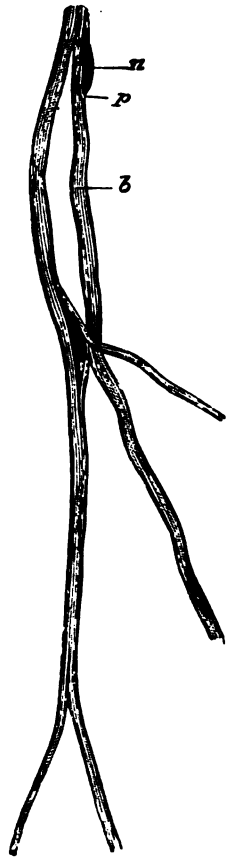
So long as the primitive sheath is accurately filled by the contained medullary substance its outline can seldom be distinguished, but sometimes, when the white substance separates at various points from the inside of the tube, the contour of the fibre becomes indented and irregular, and then the membrane of the tube may, in favourable circumstances, be discerned as an extremely faint line, running outside the deeply shaded border formed by the white substance.

In the white fibres of the brain and spinal cord the nucleated sheath is absent, and these are only invested by a medullary sheath in which nodes of Ranvier have not been detected. In consequence of the absence of the comparatively tough primitive sheath the fibres from these situations cannot be isolated for any distance without rupture, and

that for the same reason the medullary sheath readily breaks the axis-cylinder, so that this is thus left bare.

ORTION OF THE NETWORK OF FIBRES OF OM THE PNEUMOGASTRIC OF THE DOG

Fig. 143.



n; *p*, protoplasm surrounding it; *b*, ed by fibrils.

or non-medullated fibres; f **Remak.**—These occur prin- branches of the sympathetic ; they are found also in greate unt in the cerebro-spinal nerves. exceedingly pale, faintly striated arying size, which exhibit nuclei t intervals. The nuclei are ap- he surface of the fibre, and, ac-) the generally received account, a delicate homogeneous sheath, imitive sheath of the medullated must be admitted, however, with hat it is difficult or impossible to e sheath, and if this is the case, must be regarded as embedded ripheral layer of the fibre itself, longing to this. The fibres in differ also from the medullated being frequently branched and th neighbouring fibres, so as to etwork along their course ; a which is never found in the the medullated nerves. The of the olfactory nerve consist pale fibres, but these are dif- m the ordinary pale fibres in vided with a distinct nucleated

NERVE-CELLS.

re found in the grey matter of the brain and spinal cord and nglia ; they exist also in some of the nerves of special sense terminations, and occur here and there in the course of certain es. They are often named ganglion-cells.

e, nerve-cells vary greatly. Thus they may be spheroidal or th a general even outline, or they may be of an angular or igure, and it is found that the nerve-cells have a characteristic certain parts of the nervous system. For example, the cells spinal ganglia are generally of a rounded shape (see fig. 156, hose from the sympathetic ganglia more angular (fig. 155), m the grey matter of the spinal cord of an exceedingly form, and provided with numerous branching processes (fig.

144); those from the cerebral convolutions conical, those from a particular layer of the grey matter of the cerebellum, flask-or retort-shaped (fig. 145), and so on. The cells which are situated in the course of peripheral nerves are often somewhat spindle-shaped, the two poles of the spindle being prolonged into nerve fibres.

Fig. 144.

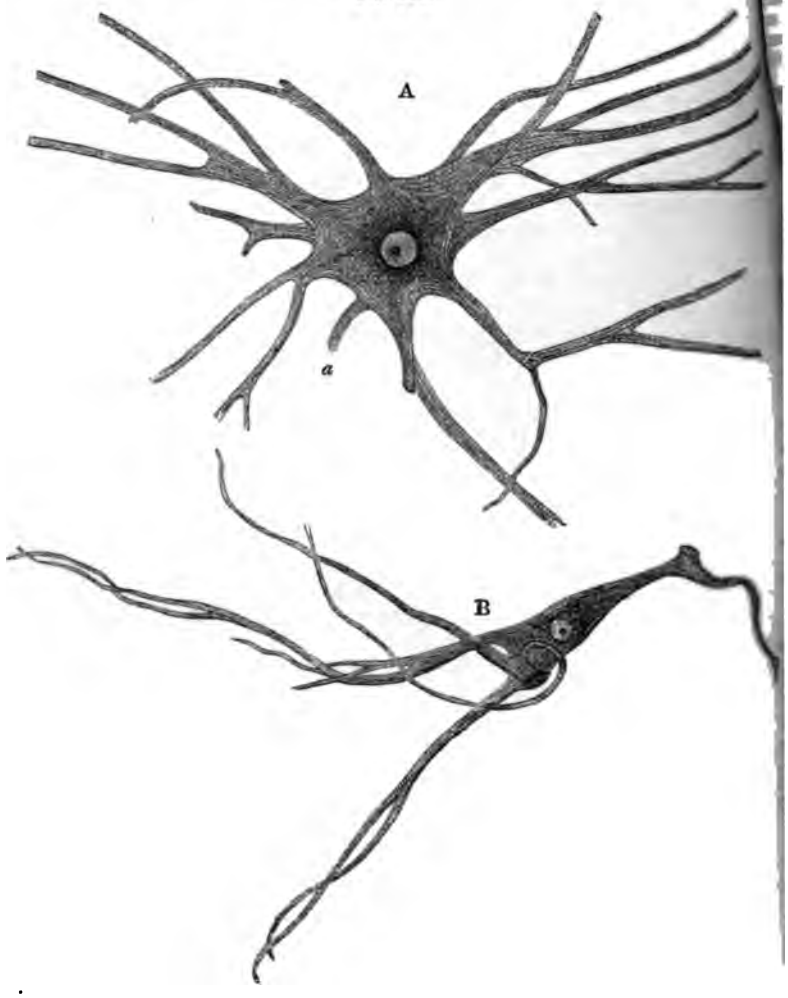
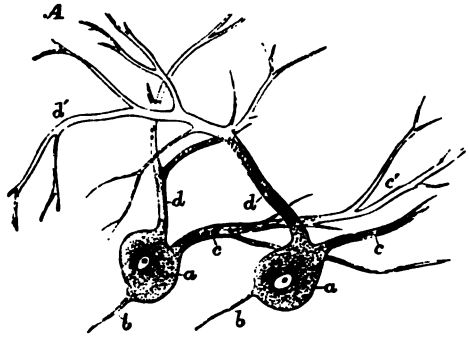


Fig. 144.—Two nerve-cells from the spinal cord of the ox, isolated after maceration in very dilute chromic acid. Magnified 175 diameters. (R.A.S.)

Each cell has a well-defined, clear, round nucleus, and a large nucleolus. The cell processes are seen to be finely fibrillated, the fibrils passing from one process into another through the body of the cell. A, from the anterior cornu of grey matter, large and stellate, with numerous processes; *a*, axis-cylinder process broken a short distance from the cell. B, probably from the posterior cornu, more fusiform in shape and apparently destitute of an axis-cylinder process.

re-cells vary much in size as well as in shape. Many of the ells in the body are very large, but there are others which are mall, and consist of little more than nuclei. The latter are lly abundant in the deeper part of the grey matter of the lum, where they form what is known as the granule-layer.

Fig. 145.



—Two nerve-cells from ortical grey matter of erebellum. Magnified iameters (Kölliker).

ucture. — The nu- f a nerve-cell (fig. usually a large clear esicle containing a listinct highly re- ; nucleolus, and, in ses, an intranuclear k. The cell-sub- s finely granular or ed, sometimes in- ly striated. It fre-

Fig. 146.

.—Ganglion-cell of a frog, highly magnified (Beale).

aight fibre ; *b*, *b*, coiled fibre ; *c*, smaller g it.

has a brownish-red tinge, but be- is, cells are often to be seen which very distinct brown or yellow patches caused by an accumula- pigment granules. The colour is n adult age than in infancy.

nerve-cell has one or more pro- and the cells are often named g to the number of processes they uni-, bi-, and multi-polar ; terms haps well-chosen, but rendered by use. A fibrillation similar to he axis-cylinder of a nerve-fibre is n the cell-processes, and it may also l passing from them into the body ll and even through this from one nto another. Some affirm that they en able to trace a connection of rils with the nucleus of the cell, is at present doubtful.

-cells which are entirely destitute of s have sometimes been described. sible that such may exist, but there s a probability that these may be processes of which have become way during the manipulation required for isolation.

been shown that many cells have at least one of their processes

prolonged as a nerve-fibre (axis-cylinder process). In the case of the bi-polar cells, especially those of a spindle-shape with a process from either end, both these processes are prolonged as nerve-fibres (fig. 154): from another point of view the cell might be looked upon as a nucleated enlargement interpolated in the course of the fibre.

Fig. 147.

Fig. 147.—Axis-cylinder process of a nerve-cell (M. Schultze).

×, ×, Portion of nerve-cell from spinal cord of ox, with axis-cylinder process, *a*, coming off from it and acquiring at *a'* a medullary sheath. Highly magnified.

In other bi-polar cells in which the processes come off on the same side of the cell, the latter often has a pyriform shape (fig. 146), the fibres being prolonged from the stalk of the pear and the nucleus of the cell being placed in the larger end. As was shown by Beale, a peculiar arrangement of the two fibres which are thus prolonged from these pear-shaped cells is found, the one being generally coiled spirally round the other for a certain distance, after which the fibres separate and take opposite directions. Cells of this kind are met with occasionally in the sympathetic ganglia both of the frog (where they were first discovered by Beale) and of the mammal.

In multi-polar cells either one or more of the cell-processes may be prolonged into nerve-fibres. In the large ramified nerve-cells of the anterior cornu of the spinal cord only one of the many processes is prolonged into a nerve-fibre. This is known as the axis-cylinder process of Deiters (fig. 148, *a*, and fig. 147), and is distinguished from the other processes of the cell by being unbranched and of a somewhat clearer and more evenly fibrillated appearance than the other processes, which branch again and again, becoming finer as they proceed, until they are eventually lost to sight in the grey matter. Other multi-polar cells, many of those in the sympathetic system for instance, possess several nerve-fibre processes (fig. 155).

Sometimes these axis-cylinder processes of a nerve-cell, especially those in the sympathetic, are continued along their whole course as pale nerve-fibres. But in many cases, at a short distance from the body of the cell, they acquire a medullary sheath and become in fact medullated nerve-fibres (fig. 147, *a'*). In the bi-polar cells (those at least of a pyriform shape), the one fibre may be prolonged as a pale fibre, the other as a medullated fibre. In other instances both fibres may become dark-bordered or both continue as pale fibres. In the uni-polar cells of the

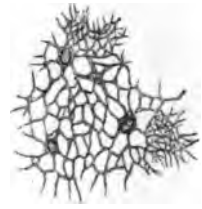
ganglia upon the posterior roots of the spinal nerves, and in some other situations the single process (which may be much convoluted near the cell and soon acquires a medullary sheath) bifurcates after a longer or shorter course, and its two branches are eventually prolonged in opposite directions along the nerve (fig. 156).

The nerve-cells in the brain and spinal cord resemble the nerve-fibres in the same parts in being destitute of any nucleated sheath, but in the ganglia each nerve-cell is inclosed in a membranous capsule, having nuclei on its inner surface and apparently continuous with the nucleated sheath of the nerve-fibre or fibres with which the cell is connected (fig. 155).

Sustentacular tissue of the nerve-centres; reticulum, neuroglia.—In the grey matter of the cerebro-spinal centre, the nerve-cells appear at first sight as if imbedded in a sort of matrix of granular substance, interposed between them in greater or less quantity, and very generally traversed by nerve-fibres. But it is very probable that the appearance of granular or molecular matter results from a confused interlacement of fine fibrils and especially of the fine ramifications of nerve-cells: or from the crushing and breaking down of such fibres in the process of examination.

Fig. 148.—Part of the reticulum from the spinal cord (Kölliker). Magnified 350 diameters.

Fig. 148.



The supporting substance which is met with in the white matter of the brain and spinal cord between the nerve-fibres also looks in section like a network, although rather more open than that in the grey matter. It was supposed by Kölliker to be a form of retiform tissue and to be composed of branched cells; accordingly he named it the *reticulum* of the nervous centres, but the term *neuroglia* which was proposed by Virchow has been more generally adopted. It is not, however, composed of cells, although these may occur in it, but it is rather of the nature of an intercellular substance which occupies the interstices between the nerve-fibres. The cells which are here and there found in it are flattened and resemble small connective tissue corpuscles, and the neuroglia of the nerve-centres has generally been regarded as consisting of connective tissue ground-substance, especially since in many places it appears fibrillated. Moreover, it is apparently in continuity with the connective tissue septa which pass into the substance of the spinal cord and brain from the investing sheath of pia mater. In the nerve-trunks, as we shall immediately see, the supporting tissue between the nerve-fibres, which also in section has the appearance of a network, is evidently composed of delicate connective tissue. By some authorities, however, the neuroglia is regarded as of the same nature as the intercellular substance of an epithelium, and the cells in it are considered to be analogous with the branched migratory cells which are sometimes found in the intercellular substance of a stratified epithelium.

Kühne and Ewald for similar reasons to those mentioned in speaking of the network of the medullated sheath of the nerve-fibre, have concluded that the

fine interlacement of fibres in the nerve-centres is also of a horny nature, and they have accordingly termed it the "horny framework."

Such being the structural elements of the nervous substance, we have next to consider the arrangement of the cells and fibres in the ganglia and nerves which they contribute to form; the intimate structure of the brain and spinal cord being treated of in a subsequent part of this work.

CONSTRUCTION OF THE NERVES OR NERVOUS CORDS.

The nerves are formed of the nerve-fibres already described, collected together and bound up in sheaths of connective tissue. A variable number of fibres inclosed in a tubular sheath forms a slender round cord

Fig. 149.

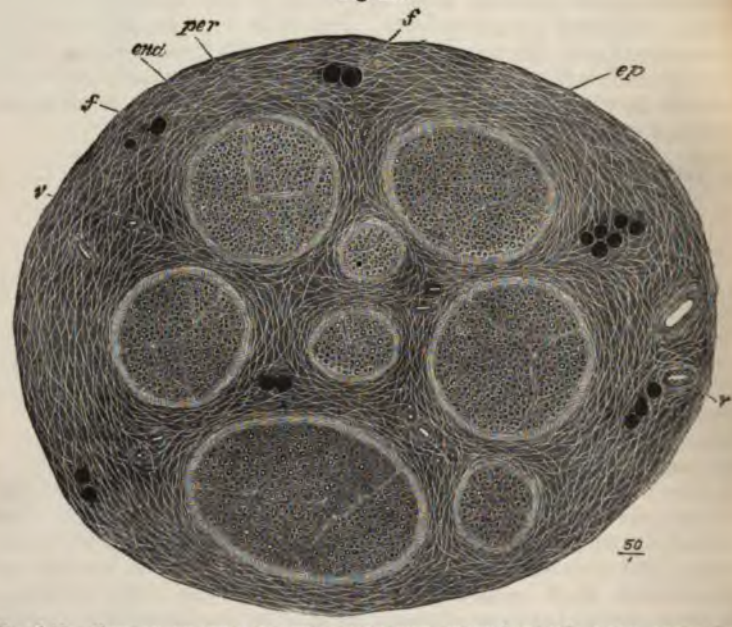


Fig. 149.—SECTION OF THE INTERNAL SAPHENOUS NERVE (HUMAN), MADE AFTER BEING STAINED IN OSMIC ACID AND SUBSEQUENTLY HARDENED IN ALCOHOL. DRAWN AS SEEN UNDER A VERY LOW MAGNIFYING POWER. (E. A. S.)

Ep, epineurium, or general sheath of the nerve, consisting of connective tissue bundles of variable size separated by cleft-like areolæ, which appear as a network of clear lines, with here and there fat-cells *f f*, and blood-vessels *v*: *per* funiculus enclosed in its lamellated connective tissue sheath (perineurium,); *end*, interior of funiculus, showing the cut ends of the medullated nerve-fibres, which are imbedded in the connective tissue within the funiculus (endoneurium). The fat-cells and the nerve-fibres are darkly stained by the osmic acid, but the connective tissue of the nerve is only slightly stained.

of no determinate size, usually named a *funiculus;* if a nerve be small it may consist of but one such cord, but in larger nerves several funiculi are united together into one or more bundles, which, being wrapped up in a common membranous covering, constitute the nerve (fig. 149).

Accordingly, in dissecting a nerve, we first come to an outward covering, formed of connective tissue, often so strong and dense that it might well be called fibrous. From this common sheath we trace connective tissue bundles passing between the funiculi, connecting them together as well as conducting and supporting the fine blood-vessels which are distributed to the nerve. But, besides the interposed areolar tissue which connects these smallest cords, each funiculus has a special sheath of its own, as will be immediately noticed.

The common sheath (fig. 149, *ep*) and its sub-divisions consist of connective tissue presenting the usual white and elastic constituent fibres of that texture, the latter being present in considerable proportion: frequently also a little fat is to be found. This common sheath has received the name of *epineurium* (Key and Retzius) ; it was formerly termed the "cellular sheath" (*vagina cellulosa*).

Fig. 150.

Fig 150.—Part of a section of one of the funiculi of the sciatic nerve of man. Magnified (after Key and Retzius).

P, Perineurium, consisting of a number of closely arranged lamellæ. *En*, processes from the perineurium, passing into the interior of the funiculus, and becoming continuous with the endoneurium, or delicate connective tissue between the nerve-fibres. The connective tissue fibrils of the endoneurium are seen cut across as fine points, often appearing to sheath the nerve-fibres with a circle of minute dots (fibril-sheath of Key and Retzius). Numerous nuclei of connective tissue cells are imbedded in the endoneurium ; *v*, section of a blood-vessel.

The special sheath of a funiculus, termed the *neurilemma* or *perineurium* (fig. 149, *per.*, 150, P.), is also formed of connective tissue, but is far more distinctly of a lamellar nature, and indeed may be stripped off in the form of a tube from the little bundle of nerve-fibres of which the funiculus consists. The perineurium is not formed of a single lamella but of several, which are separated from one another by interlamellar clefts moistened with lymph. The separation is not everywhere complete, for here and there bundles pass across, connecting the several lamellæ. Moreover, the outermost lamella is joined by connective tissue bundles and laminæ of the epineurium, and the innermost gives off flattened prolongations (fig. 149, *end*), to form imperfect septa between the groups of nerve-fibres within the funiculus.

Although the lamellæ of the perineurium are very thin, each is formed of at least three strata. Thus the main substance of the lamellæ is composed of a connective tissue, in which both white fibres and elastic elements are found, the white fibres having for the most part a transverse disposition. The elastic elements lie in greater abundance nearer the

surfaces of the lamella, and often occur in the form of patches or incomplete membranes of elastic substance (fig. 73, p. 71), as well

Fig. 151.

Fig. 151.—A PORTION OF A SMALL NERVE-TRUNK FROM THE THORAX OF A MOUSE, TREATED WITH NITRATE OF SILVER (Ranvier). MAGNIFIED.

Cross markings are seen at the nodes, and the layer of flattened epithelioid cells which covers the surface is also brought into view.

as in the form of a fine network of fibres. On both its surfaces, each lamella is entirely covered with a layer of exceedingly delicate flattened epithelioid cells, which thus serve also to bound the clefts between the lamellæ. The outlines of the cells are brought into view by the silver treatment (fig. 151).

The funiculi of a nerve although not all of one size, are all sufficiently large to be readily seen with the naked eye, and easily dissected out from each other. In a nerve so dissected into its component funiculi, it is seen that these do not run along the nerve as parallel insulated cords, but join together obliquely at short distances as they proceed in their course, the cords resulting from such union dividing in their further progress to form junctions again with collateral cords; so that in fact the funiculi composing a single nervous trunk have an arrangement with respect to each other similar to that which is found to hold in a plexus formed by the branches of different nerves. It must be distinctly understood, however, that in these communications the medullated nerve-fibres do not join together or coalesce. They pass off from one nervous cord to enter another, with whose fibres they become intermixed, and part of them thus intermixed may again pass off to a third funiculus, or go through a series of funiculi and undergo still further intermixture; but throughout all these successive associations (until near the termination of the nerve) the fibres remain individually distinct, like the threads in a rope.

The nerve-fibres are separated from one another, and supported within the funiculus by delicate connective tissue, the fibrils of which run for the most part longitudinally, appearing in section as fine points (fig. 150). This tissue has been distinguished as the *endoneurium* by Key and Retzius. It is continuous with the septa which pass in as above mentioned from the innermost lamella of the perineurium, and it serves to support also the capillary blood-vessels which are distributed to the nerve.

Lying alongside each other, the fibres of a funiculus form a little skein or bundle, which runs in a waving or serpentine manner within its sheath; and the alternate lights and shadows caused by the successive bendings being seen through the sheath, give rise to the appearance of alternate light and dark cross stripes on the funiculi, or even on larger cords consisting of several funiculi. On stretching the nerve, the fibres are straightened and the striped appearance is lost. Both the peri-

eurium and endoneurium accompany the nerves in all their divisions, some cases as far as their peripheral terminations. In the finest ranches the perineurium generally becomes reduced to a single nnective tissue lamella, covered on both surfaces by epithelioid cells. n this condition it is sometimes known as the sheath of Henle.

Both the cerebro-spinal and the sympathetic nerve-trunks are con-tructed in the manner above described, but the fibres of the cerebro-pinal nerves are chiefly of the white or medullated kind, while in nerves elonging to the sympathetic system non-medullated fibres for the most art preponderate. But very few nerves are composed exclusively of one r the other kind of fibre.

The cerebro-spinal nerve-trunks and their branches always present a rilliant whitish aspect, whereas the sympathetic nerves vary in ppearance, some being whiter, others grey or reddish in colour. The ore grey-looking branches or bundles consist of a large number of e pale fibres mixed with a few of the medullated kind (fig. 152) ; the niter cords, on the other hand, contain a proportionally large amount of

Fig. 152.

. 152.—A SMALL BUNDLE OF NERVE FIBRES FROM THE SYMPATHETIC NERVE. (Key and Retzius.)

The bundle is composed of pale nerve-fibres, with the exception of the fibre *m*, *m*, ich is enclosed here and there by a thin medullary sheath ; *n*, *n*, nuclei of pale fibres.

edullated fibres, and fewer of the grey ; and in some parts of the nerve ey fasciculi and white fasciculi, respectively constituted as above scribed, run alongside of each other in the same cords for a consider-le space without mixing. This arrangement may be seen in some of the anches of communication with the spinal nerves, in the trunk or cord ich connects together the principal chain of sympathetic ganglia, and the primary branches proceeding from thence to the viscera. In the t-mentioned case the different fasciculi get more mixed as they vance, but generally it is only after the white fasciculi have passed rough one or more ganglia that they become thoroughly blended with e grey ; and then, too, the nervous cords receive a large accession of ey fibres (apparently derived from the ganglia), which are mixed up th the rest, and take off more and more from their whiteness.

Differences are observed among the cerebro-spinal nerves in the pro-rtionate amount of the two kinds of fibres which they respectively ntain, and in the size of their white fibres. Volkmann and Bidder owed that whereas nerves going to voluntary muscles are chiefly

composed of large fibres, those distributed to the integuments have many small ones, and have also a larger proportion of grey fibres, moreover the anterior roots of the spinal nerves which are composed almost exclusively of motor fibres contain more large fibres in proportion than do the posterior or sensory roots. The vagus nerve contains a considerable proportion of grey fibres.

Vessels and Lymphatics.—The blood-vessels of a nerve after dividing into small branches in the epineurium and giving offsets to the groups of fat-vesicles which are there met with, pierce the layers of the perineurium obliquely, being supported by the connective tissue bundles which unite the lamellæ, and conducted into the interior of the funiculus along the septa before mentioned. Here they break up into fine capillaries which for the most part run parallel with the fibres, but are connected at intervals by short transverse branches, thus forming a network with long narrow meshes. Some of the capillaries may be observed to form loops. Lymphatic vessels are found in the epineurium, but within the funiculi there are no distinct vessels for the conveyance of lymph. It is found however that coloured fluid which is injected by means of a fine cannula into the interior of a funiculus finds its way into the lymphatics of the sheath after passing through the clefts between the lamellæ of the perineurium, so that undoubtedly a connection exists between these perineural clefts and the lymphatic system.

Course of the nerve-fibres in the nerve-trunks.—Neither in their course along the nervous cords, nor in the white part of the nerve-centres, do the medullated fibres anastomose together, nor are they observed except in rare instances to divide into branches until they approach their termination. But the nerve-trunks themselves continually ramify, and the branches of different nerves not unfrequently join with one another. The branches are of course formed by collections of nerve-fibres and it follows therefore that when two branches of nerves join, fibres pass from the one nerve-trunk to become associated with the other in their further progress, or the communication may be reciprocal, so that after the junction each nerve-trunk contains fibres derived from two originally distinct sources. In other cases the branches of a nerve, or branches derived from two or from several different nerves, are connected in a more complicated manner, and form what is termed a plexus. In plexuses—of which the one named "brachial" or "axillary," formed by the great nerves of the arm, and the "lumbar" and "sacral," formed by those of the lower limb and pelvis, are appropriate examples—the nerves or their branches join and divide again and again, interchanging and intermixing their fibres so thoroughly that, by the time a branch leaves the plexus it may contain fibres from several or even from all the nerves entering the plexus. Still, as in the more simple communications already spoken of, the fibres, so far as is known, remain individually distinct throughout.

In some instances of nervous conjunctions certain collections of fibres, after passing from one nerve to another, take a retrograde course in that second nerve, and, in place of being distributed peripherally with its branches, turn back to its root and rejoin the cerebro-spinal centre. An instance of this occurs, as shown by Volkmann, in the connection between the second and third cervical nerves of the cat, in that of the fourth cranial nerve with the first branch of the fifth, and of the cervical nerves with the spinal accessory and the descendens noni.

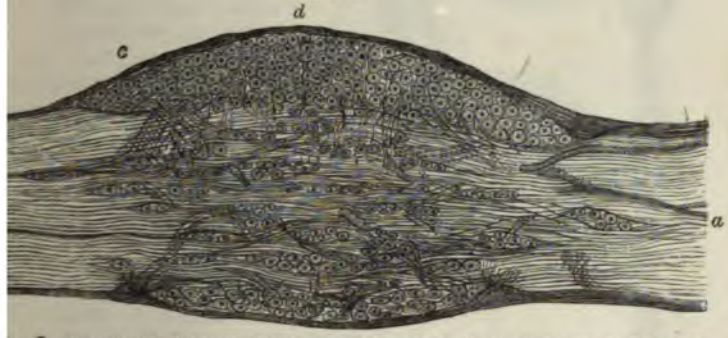
CONSTRUCTION OF THE GANGLIA.

nation.—Ganglia are found in the following situations—viz. : 1. e posterior root of each of the spinal nerves ; on the corresponding of the fifth nerve of the encephalon ; and on the facial, glosso-ngeal and pneumogastric nerves ; also on the branches of certain o-spinal nerves. 2. In a series along each side of the vertebral n, connected by nervous cords, and constituting what was long ered as the trunk of the sympathetic. 3. On branches of nerves, ally of the sympathetic ; occurring numerously in the abdomen, , neck, and head ; generally in the midst of plexuses, or at the of union of two or more branches. Those which are found in l of the fossæ of the cranium and face are for the most part placed junction of fine branches of the sympathetic with branches, larger, of the cerebro-spinal nerves.

ganglia differ widely from each other in figure and size : most of which have been longest known to anatomists are conspicuous s ; but by the researches of Remak and others, it has been shown ere are numerous small or microscopic ganglia disposed along the es of nerves distributed to the heart, the lungs, and some other ; and also connected with fine plexuses of nerves between the f the stomach and intestines.

ucture.—Ganglia are invested externally with a thin, but firm osely adherent covering of connective tissue, continuous with the ral and perineural sheath of the nerves : this outward covering processes inwards through the interior. A section carried through lion in the direction of the nervous cords connected with it, dis- collections of nerve-cells, between which the nerve-fibres pass

Fig. 153.



.—LONGITUDINAL SECTION THROUGH THE MIDDLE OF A GANGLION ON THE POS- R ROOT OF ONE OF THE SACRAL NERVES OF THE DOG, AS SEEN UNDER A LOW FYING POWER. (E.A.S.)

ve-root entering the ganglion ; *b*, fibres leaving the ganglion to join the mixed erve ; *c*, connective tissue coat of the ganglion ; *d*, principal group of nerve- th fibres passing down from amongst the cells, probably to unite with the nally coursing nerve-fibres by T-shaped junctions (see text).

3). The nervous cords on entering lay aside the perineural , which become merged into the general connective tissue of the and spread out into smaller bundles, between which the

ganglion-cells are interposed ; and the fibres are gathered up a cords, furnished with perineural sheaths, on issuing from the

Fig. 154.

Fig. 154.—A BIPOLAR NERVE-CELL, WITH ITS POLES PROLO MEDULLATED NERVE-FIBRES (Key and Retzius).

The whole is invested by the primitive sheath. *R*, *R*, Ranvier.

The nerve-cells have mostly a round, oval, or figure. Each cell is inclosed in a transparent cap nuclei upon its inner surface, (figs. 155, 156) ; these are continuous with the primitive sheaths of the ne Schultze).

Fig. 155.

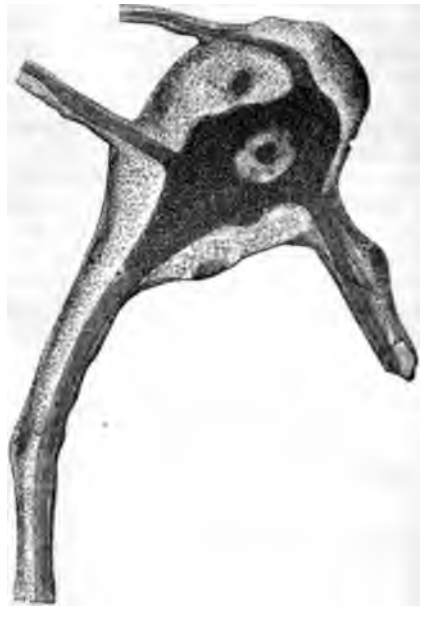
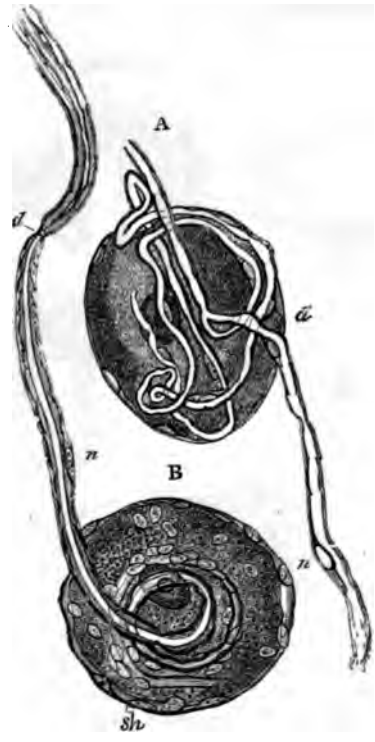


Fig. 155.—A GANGLION-CELL WITHIN ITS SHEATH ; FROM TI SYMPATHETIC. HIGHLY MAGNIFIED. (Key and Retzius

Of the relation between the nerve-fibres in a gang the ganglion-cells, it is probable that some fibres r through without being connected with the cells, l every nerve-cell is connected with a fibre or with fib the case of multi-polar cells (fig. 155), such as are the sympathetic ganglia, each of the branches of the all probability continuous with a nerve-fibre, and t is certainly the case with bipolar cells, at least those the two poles are prolonged from opposite extremiti cell as in the spinal ganglia of fish (fig. 154), as

ıe pyriform cells before noticed (see p. 148, and fig. 146) in which processes arise from a part of the cell near one another, and are inued in opposite directions, either at once, or after the one fibre made two or more spiral coils around the other or straight fibre. -polar cells are found in the spinal ganglia of the higher vertebrates 156). In them the single nerve-fibre process is observed to divide re long into two fibres (*d*), which traced far enough are found to in opposite directions toward the ends of the ganglion. Some- s the branches are of equal size, but they are often unequal, one g decidedly smaller than the other. As in all cases of a division medullated nerve-fibre, the bifurcation takes place at a node of

Fig. 156.



156.—Two NERVE-CELLS FROM A NAL GANGLION (HUMAN) (Retzius).

, Nucleated sheath; *n*, *n*, nuclei of primitive sheath of the nerve. From cell a fibre can be seen to arise, and r a convoluted course on the surface of nerve-cell, to bifurcate (opposite *d*); a which point the divisions pass either he opposite direction to one another, as A, or at first in the same direction as B. The nuclei of the sheath of the ve-cell are all represented in B, but ly those seen in profile have been presented in A.

anvier, and this may be the first ode from the cell, or the nerve- re may pass two or three or re nodes before thus dividing. e cell-process, which usually quires its medullary sheath very n after leaving the cell, is en convoluted over the surface or around the cell; this is ecially the case in the human al ganglia. Its bifurcation, in other words its junction a nerve-fibre traversing the glion is often T-shaped.

hese T-shaped divisions were noticed by Ranvier. They been found by Retzius in the al ganglia of all classes of vertebrates above fishes—where the cells bipolar like that shown in fig. 154; and also in man, in the spinal glia, in the jugular and cervical ganglia of the vagus, the geniculate glion of the facial and the Gasserian ganglion of the trigeminal; not in the otic, the sphenopalatine, the sub-maxillary and the ciliary glion, the cells of all of which are multi-polar, and hence resemble which are found in the sympathetic.

ls which are transitional in character between the bipolar cells of most and the unipolar cells with forked process of the higher vertebrates, seem

to occur, as Freud has shown, in Petromyzon, in which, in addition to the ordinary bipolar cells, some of the cells have their two processes coming off quite close to one another, and others are unipolar with a short single process which soon bifurcates to form two nerve-fibres passing in opposite directions.

ORIGINS OR ROOTS OF THE NERVES.

The cerebro-spinal nerves, as already said, are connected by one extremity to the brain or to the spinal cord, and this central extremity of a nerve is, in the language of anatomy, named its origin or root. In some cases the root is single, that is, the funiculi or fibres by which the nerve arises, are all attached at one spot or along one line or tract; in other nerves, on the contrary, they form two or more separate collections, which arise apart from each other and are connected with different parts of the nervous centre, and such nerves are accordingly said to have two or more origins or roots. In the latter case, moreover, the different roots of a nerve may differ not only in their anatomical characters and connections, but also in function, as is well exemplified in the spinal nerves, each of which arises by two roots, an anterior and a posterior—the former containing the motor fibres of the nerve, the latter the sensory.

Fig. 157.

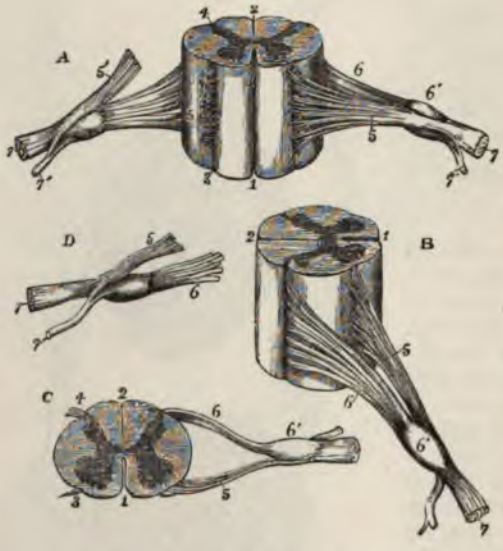


Fig. 157.—Roots of one of the spinal nerves issuing from the spinal cord. (A. T.)

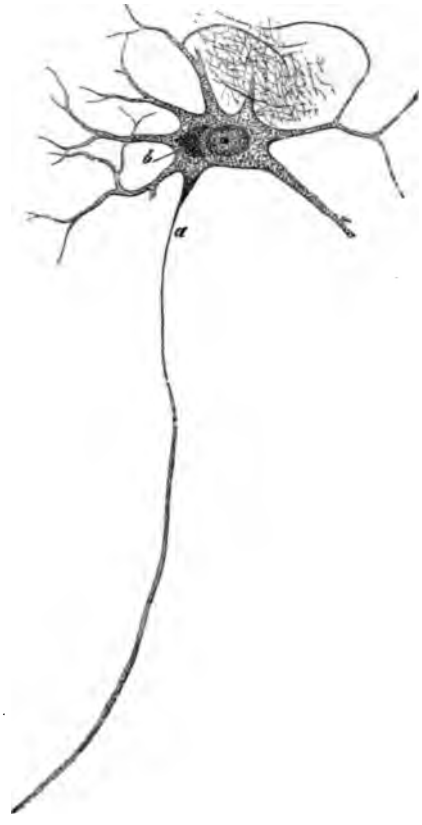
A, from before; B, from the side; C, from above; D, the roots separated; 5, 5, anterior root; 6, 6, posterior root with ganglion, 6'. The full description of this figure will be found in the chapter on the cerebro-spinal nervous axis.

The fibres of a nerve may be traced to some depth in the substance of the brain or spinal cord, and hence the term "apparent or superficial origin" has been employed to denote the place where the root of a nerve is attached to the surface, in order to distinguish it from the "real or deep origin" which is beneath the surface and concealed from view.

If the deep origin be traced out, it will always be found that the nerve-fibres arise from portions of the grey substance of the nerve-centre; these portions of grey substance being sometimes known as the "nuclei of origin" of the nerve. In many cases it has been shown that the individual nerve-fibres originate as prolongations of the

ve-cells in the grey substance (fig. 158), and where from the small-
s of the cells, or the complexity of arrangement of the fibres it has not
n possible to trace any such connection, it is probable that it exists none
less. It is somewhat doubtful whether the nerve-fibres originate in
r other way than directly as cell-prolongations. The intermediate
stance of the grey matter of the brain and spinal cord is pervaded
rywhere by an exquisitely fine network of nerve-fibrils, and it has
n supposed that on the one hand the ramified processes of the multi-

Fig. 158.



. 158. — RAMIFIED NERVE-CELL FROM ANTERIOR CORNU OF SPINAL CORD OF MAN (from Gerlach).

a, axis-cylinder process. *b*, clump pigment granules. Above the cell en part of the network of fibrils tioned in the text.

lar cells lose themselves in his network, and on the other nd that some of the nerve-bres may take origin from e same general network. So at there would be in this ay through the intermediate bstance of the grey matter a neral connection, not only the nerve-cells, but through ese and their axis-cylinder ocesses also of the nerve-res of the cerebro-spinal stem.

The fibres of origin of a rve on quitting the brain or inal cord are in most cases lected into funiculi and quire the connective tissue-aths above described. These aths are in continuity with membranes investing the ain and spinal cord, and their ations will be better under-od after the membranes in estion have been described.

TERMINATION, OR PERIPHERAL DISTRIBUTION, OF NERVES.

It may be stated, generally, and apart from what may apply to special odes of termination, that, in approaching their final distribution, the res, medullated and non-medullated, usually divide into branches, e division in the case of medullated fibres always occurring in the nation of a node of Ranvier (fig. 159). The axis-cylinder participates the division; and since the white fibres frequently lose their medullary eath shortly before they terminate, they are then represented by the

axis-cylinder and its ramifications, although the primitive sheath may sometimes some little way along the branches after the medullary sheath has ceased. By repeated division the fibres become smaller and smaller; and whilst some of the resulting small fibres may be simple, many are really bundles of exquisitely fine fibrils.

The fibres bear nuclei, which probably appertain to the prolongations of the primitive sheath; the nuclei are common at the bifurcations of the fibres, where they are of a triangular or irregular shape. These pale fibres often join into plexuses; but their ultimate disposition in different parts will be treated of below. As has already been explained the original dark-bordered fibres which thus undergo division and

Fig. 159.

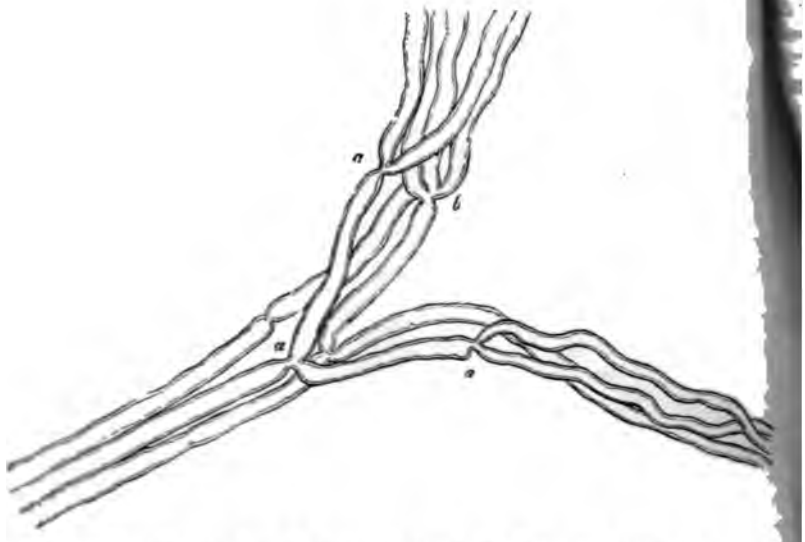


Fig. 159.—Small branch of a muscular nerve of the frog, near its termination, showing divisions of the fibres. Magnified 350 diameters (Kölliker).

a, into two; *b*, into three.

change, or which may proceed singly to end in a different and special manner, are commonly provided with a tolerably strong connective tissue sheath with nuclei, which, as it stands well apart from the dark borders of the fibre, is very conspicuous (Henle's sheath). This is derived from the perineurium which incloses the funiculi of the nerve-trunks, and, as these part into smaller collections and single fibres, undergoes a corresponding division, and finally sends sheaths along single fibres. Within the sheath of Henle fine longitudinal connective tissue fibres, with interspersed corpuscles, are seen surrounding the nerve-fibre or fibres. This tissue is a prolongation of the endoneurium.

In further treating of the termination of nerves, it will be convenient to consider the sensory and motor nerves separately.

TERMINATIONS OF SENSORY NERVES.

The sensory or afferent nerves end either in cells or in free nerve-
adings, which may be simple or plexiform, and may be inclosed by
lls or have an independent distribution. Of the sensory nerves which
rminate in cells, the best known and longest recognised are those
hich are found in the organs of special sense. Here the nerves or
ther their axis-cylinders, usually after dividing into fibrils, appear to
d in modified epithelium-cells, which are termed *sensory* or *nerve-
ithelium cells*, and are characterized for the most part by the pos-
ssion of a peculiar styliform process, directed peripherally, while on
e other hand they are connected centrally, as it would seem, with the
erve-fibres of the sense-organ. In the different organs of special sense
ese nerve-epithelium cells undergo peculiar modifications, and present
rtain complexities of structure which will be more properly treated
f in the parts of this work which are devoted to the description of
hose organs.

Of the ordinary sensory nerves, including those which are devoted to
he perception of tactile sensations, some end in, or in contact with, cells
which are originally derived from an epithelium, but have undergone
much less modification in structure than the nerve-epithelium cells above
mentioned. They are termed *tactile cells* by Merkel, and he states that
they may occur scattered here and there in the deeper parts of a stratified
epithelium, such as the epidermis; but it is more common to find the
cells in question in the true skin or other connective tissue structure,
and arranged in groups of two or more, united together by a con-
nective tissue envelope into a terminal nervous organ or *tactile end-
organ*. According to most observers the axis-cylinder of the nerve ends
between, not in, the tactile cells which form the chief part of the end-
organ, and the cells serve rather to protect the actual nervous termina-
tion than to receive it. Of the end-organs which seem thus constructed,
the best known are the *tactile corpuscles of Meissner*, the *corpuscles of
Grandry*, which occur in birds, and the *round end-bulbs* of the human
conjunctiva. In other end-organs (*cylindrical end-bulbs*, *Pacinian
bodies*), the axis-cylinder passes into and seems to end abruptly in a
central protoplasm-like mass, termed the core, which is surrounded by
a simple or multiple expansion of the perineural sheath of the nerve,
ut here also, as the study of its development shows, the core was
riginally formed of agglomerated cells. But in many nerves of general
nsation, the nerve-fibres do not terminate in a specialized organ, but
e axis-cylinder becomes again and again branched, until it is resolved
to filaments of extreme tenuity, its ramifications, which often unite
nstantly with one another and with the branches of neighbouring
bres in a plexiform manner, consisting of small bundles of ultimate
brils, which pass at length to terminate freely, and with minute
ricose enlargements, in the tissue to which they are distributed.
his is the mode of ending of some of the more superficially placed
rves of the general integument, where many of the nerve-fibrils end
tween the cells of the stratified epithelium.

Tactile cells (Merkel). Tactile cells, isolated or in groups, but in the latter
se not collected together to form a tactile end-organ, are described by Merkel
occurring in the deeper layers of the epidermis and sometimes in the sub-
cent true skin over almost the whole of the body. In animals they are

especially numerous in parts of the skin which are devoid of hairs, as in that which covers the soles of the feet, and on the snout, as well as amongst the epithelium-cells of the hard palate. The cells in question are round or pyriform in shape, and prolonged at one part into the axis-cylinder of a nerve-fibre: in cases where the axis-cylinder is ramified, it may be connected with more than one of these cells. Each cell is stated to be inclosed by a cell-membrane which is continuous with a prolongation of the primitive sheath of the nerve-fibre. When the tactile cells occur in the superficial layers of the cutis vera instead of amongst the cells of the epidermis they are found to be inclosed in a capsule of connective tissue, which is pierced by the axis-cylinder of the nerve-fibre as this passes to apply itself to one of the surfaces of the usually flattened cell. Such a cell, inclosed in a capsule and forming the termination of a nerve-fibre, represents, according to Merkel, the tactile end-organ in its simplest form. The existence of tactile cells such as are described by Merkel is, however, not generally admitted by histologists.

Fig. 160.

Fig. 160. — Two tactile cells in the deeper part of the human epidermis. (Merkel.)

Tactile corpuscles or touch-bodies (*Corpuscula tactûs*)—(figs. 161, 162). These were discovered by R. Wagner and Meissner in the papillæ of the skin of the hand and foot, where they are of an oval shape, nearly $\frac{1}{30}$ of an inch long and $\frac{1}{80}$ of an inch thick. One, two, or more medullated nerve-fibres run to the corpuscle and either at once or after winding round it two or more times, pass into its interior and become lost to view. The tactile corpuscles were described by their discoverers as consisting of a soft structureless core or central part, in which the nerve-fibres were thought to terminate by bulbous enlargements, and of an inclosing capsule of connective tissue, continuous with the perineurium of the nerve,

Fig. 161.

Fig. 161. — Section of skin showing two papillæ and deeper layers of epidermis. (Biesiadecki.)

a, Vascular papilla with capillary loop passing from subjacent vessel *c*; *b*, nerve papilla with tactile corpuscle, *t*. The latter exhibits transverse fibrous markings: three nerve-fibres, *d*, are represented as passing up to it: at *f f* these are seen in optical section.

composed for the most part of transverse or spiral fibres and
i, so arranged as to give the little body somewhat the aspect of a
ature fir-cone. It would appear however that a soft core, like that of
Pacinian corpuscles to be presently described, does not in reality
in these corpuscles, but that the main substance of the touch-
y is composed of connective tissue, prolonged inwards from
capsule in the form of imperfect membranous septa (fig. 163 A),
ween which are supported the convolutions and ramifications of
nerves, and the enlargements in which the branches of the axis-
inder eventually end (small tactile cells according to Merkel). These
minal enlargements, which are either pyriform or globular in shape,
always placed near the capsule, and in small tactile corpuscles may
ically project beyond it. On entering the corpuscle the nerve-
es for the most part lose their medullary sheath, but some retain
r a short while, or it may reappear here and there in the course

Fig. 162. Fig. 163.

162.—TACTILE CORPUSCLE WITHIN A PAPILLA OF THE SKIN OF THE HAND, STAINED WITH CHLORIDE OF GOLD. HIGHLY MAGNIFIED. DRAWN BY W. FLEMMING, FROM A PREPARATION BY E. FISCHER.

Ep, epidermis; only the outlines are indicated. The convolutions of the nerve-
within the corpuscle are well seen.

Fig. 163.—TACTILE CORPUSCLES FROM THE PALM OF THE HAND, SEEN IN SECTION. (Merkel.)

A, Longitudinal section showing the interior traversed by connective tissue septa
from the capsule; the nerve-fibres are cut across. B, transverse section at the
of entrance of a nerve-fibre, showing the axis-cylinder branching. Other nerve-
are cut obliquely.

the fibres. The axis-cylinders, which are often varicose, have, as
intimated, a convoluted course before ending in their terminal
largements.

The absence of a central core such as is found in the Pacinian corpuscles, and
some end bulbs, was first pointed out by Langerhans and afterwards by Thin.
The latter observer stated as the result of his observations, that tactile corpuscles
ould be divided into simple or compound, according as they receive one or a
reater number of nerve-fibres each nerve-fibre passing to one distinct corpuscle,

and the larger corpuscles being compounded of two or more simple ones. On the other hand, even in the same papilla, several small corpuscles may occur near to but distinct from one another.

Tactile corpuscles have been found in the following parts:—skin of the fingers, palms and soles, back of the hands and feet, volar surface of the forearm, margins of the lips, conjunctiva lining the eyelids and in the mucous membrane near the tip of the tongue.

What appear to be tactile corpuscles of simple structure were discovered by W. Krause in certain parts of the external generative organs, both in the male and female, and were named by him "genital corpuscles." Each corpuscle is composed of connective tissue, containing numerous nucleated cells, and appears not to be provided with any special capsule. The axis-cylinder of the nerve-fibre entering at one pole of the somewhat oval corpuscle (fig. 164) may either pass straight or with one or two bendings through the corpuscle, and end by a tapering (A) or by a dilated extremity (B) near the opposite pole (often projecting beyond the general body of the organ, as in B), or it may be much convoluted in its passage through the organ, so as to render it a matter of difficulty to trace its course and mode of termination. Frequently the fibre divides into two or more branches within the corpuscle, and each of these may end in a swollen extremity, which projects beyond the main part of the corpuscle; the latter then acquires a peculiar knobbed or mulberry-like aspect. The arrangement of the cells in these corpuscles seems to vary considerably. Sometimes they are chiefly collected at the exterior, leaving the part traversed by the axis-cylinder free from cells and of a fibrous appearance (fig. 164 A); but in others there is an agglomeration of cells in the centre, and the corpuscles then closely resemble the spheroidal end-bulbs of the human conjunctiva.

Fig. 164.

Fig. 164. — TACTILE CORPUSCLES FROM THE CLITORIS OF THE RABBIT. (Izquierdo.)

Pacinian bodies.—In dissecting the nerves of the hand and foot, certain small oval bodies like little seeds, are found attached to their branches as they pass through the subcutaneous fat on their way to the skin; and it has been ascertained that each of these bodies receives a nervous fibre which terminates within it. The objects referred to were more than a century ago described and figured by Vater, as attached to the digital nerves, but he did not examine into their structure, and his account of them seems not to have attracted much notice. In more recent times, their existence was again pointed out by Cruveilhier and other French anatomists, as well as by Pacini of Pisa, who appears to be the first writer that gave an account of the internal structure of these curious bodies, and clearly demonstrated their essential connection with nerve-fibres. The researches of Pacini were followed up by Henle and Kölliker, who named the corpuscles after *him*; and the Pacinian corpuscles have since been the subject of numerous

lamellæ of the perineurium of a nerve. Each lamella (fig. 167) of a connective tissue layer formed both of white fibres, whic mostly a transverse direction and are placed near its surfaces (of elastic fibres, which pass in various directions, and (with oc bands of white fibres) stretch across the thickness of the lamell one surface to the other (*c*). The surfaces of the lamellæ are

Fig. 166.

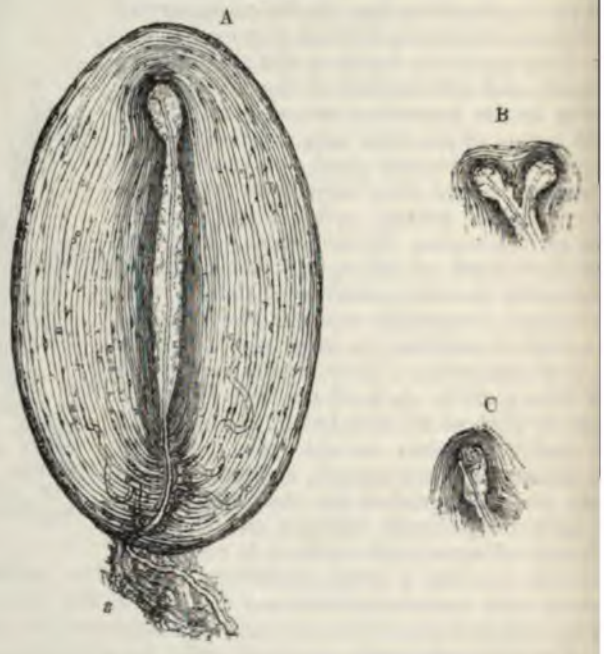


Fig. 166.—A, MAGNIFIED VIEW OF A PACINIAN BODY FROM THE CAT'S MESE

(From a drawing by Professor J. Marshall, F.R.S.)

s, Stalk with nerve-fibre passing to the corpuscle. One or two capillaries are issuing from it between the tunics. B and C represent the termination of with the distal end of the core and adjoining tunics, and illustrate varieties of ment. In B the fibre is bifurcated.

with a layer of epithelioid cells (*aa*), which can be brought to vi nitrate of silver, and then their continuity with the similar cells perineurium is made manifest (fig. 168). The tissue of each la lax as compared with that of the layers of the perineurium, interstices between the fibres are occupied by a considerable q of watery fluid, probably of the nature of lymph, and containin sionally lymph-corpuscles. This fluid in the fresh state t obscure the delicate fibres of the lamellæ, so that the adjacent of epithelioid cells belonging to the successive lamellæ stand out

The nerve-fibre is single as it runs along the peduncle, unless when the latter supports two corpuscles; it retains the medullary sheath until it reaches the core, into which the axis-cylinder alone passes, freed from its primitive and medullary sheaths (fig. 169, *c.f.*). In its course through the core it is somewhat flattened, and presents the appearance either of a pale, finely striated, and very faintly outlined band or stripe, or of a darker and more sharply defined narrow line; differing thus in appearance according as its flat side or its edge is turned towards the eye. The contrast in the appearance of the fibre before and after entering the core is well exhibited after treatment with osmic acid, which

Fig. 169.

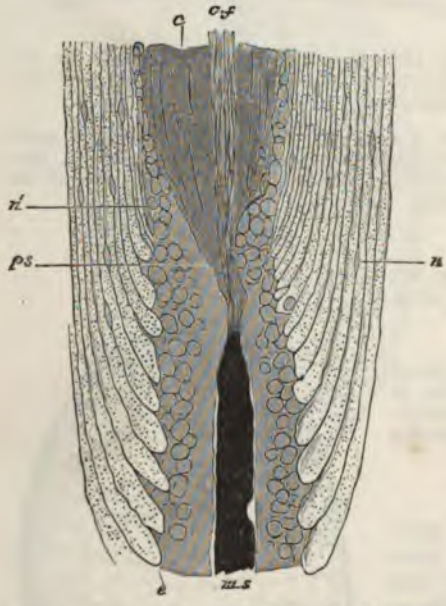


Fig. 169.—PART OF PACINIAN BODY SHOWING THE NERVE-FIBRE ENTERING THE CORE. FROM AN OSMIC ACID PREPARATION. (E. A. S.)

ms, entering nerve-fibre, the medullary sheath of which is stained darkly, and ends abruptly at the core; *p*, *s*, prolongation of primitive sheath, passing towards the outer part of the core; *c.f.* axis-cylinder passing through the core as the central fibre; *c*, some of the inner tunics of the corpuscle, enlarged where they abut against the canal through which the nerve-fibre passes; *n*, nuclei of the tunics; *n'*, nuclei of the endoneurium, continued by others in the outer part of the core.

stains the medullary sheath deeply, whereas the axis-cylinder is far less stained. It sometimes happens that the fibre regains its double contour for a short space, and changes again before it terminates; this is especially liable to occur while it passes through a sharp flexure in a crooked core. The fibre usually ends by a sort of knob at the further extremity of the core, which is here itself somewhat dilated. The knob, often finely granular, appears to be an expansion of the axis-cylinder, and is sometimes of considerable size. It may be of an irregular shape with processes branching outwards from the sides, and in such cases has been taken to represent a nerve-cell; but the characteristic nucleus of the latter is absent. The ultimate destination of the processes is unknown. The axis-cylinder shows the usual longitudinal fibrillation as it passes through the core, and the fibrils become somewhat spread out as they pass into the terminal expansion. In many cases the fibre, either immediately before terminating, or in its course through the core, divides into branches: a division into three has been observed, but this is more rare. In case of division of the fibre, the core is ·ally, but not invariably, divided in a corresponding measure,

nd the inner tunics present a figure in keeping with it. It is orthy of remark, that the nerve-fibre in its course along the core ns almost exactly in the axis of the latter, and it maintains is position even when passing through the abrupt flexures of an regularly shaped core. It sometimes happens that a fibre passes ite through one corpuscle and terminates in a second, resuming original size and dark outline while passing from the one to the her; and it is said that a nerve-fibre may go through two Pacinian dies without terminating in either, returning again to the parent rve in form of a loop (Pappenheim). A little artery enters the acinian bodies along with the nerve, and soon divides into capillary anches, which run up between the tunics. They then form loops, nd return by a similar route into a vein corresponding to the artery: single capillary usually accompanies the nerve as far as the core, nd passes some way on the wall of the latter, sometimes with a iral direction (Bowman). Occasionally a vessel enters the corpuscle the distal end and passes towards the core, uniting the tunics in s passage.

As to the nature of the core of the Pacinian body, there is considerable difference of opinion. That it is not merely an expansion of the medullary sheath the nerve-fibre, as was thought by Engelmann, is shown by its behaviour ith staining fluids, and particularly osmic acid (see fig. 169). Moreover in ses where the medullary sheath is prolonged for some distance into the core, occasionally happens, the contrast between it and the substance which rrounds it, is very marked.

In considering the true nature of the core, it should first be remarked that it is not mpletely homogeneous and structureless, as on superficial examination it seems be, but exhibits at least in its outer part longitudinal striation and nuclei in riable number. In transverse section the striation in the outer part of the re is seen to be concentric, and produced apparently by flattened nucleated lls, which are so arranged as to inclose the inner and more homogeneous rtion. At the entrance of the nerve-fibre into the core the nucleated cells re spoken of are to all appearance continuous with a layer of cells in the doneurium around the entering nerve-fibre, so that this outer part of the re, at least, might be regarded as formed by an expansion of endoneurium. he inner part, on the other hand, that, namely, which is in immediate contact ith the axis-cylinder, appears structureless. In its behaviour towards staining -agents, it resembles protoplasm, and it is possible that it may represent the rotoplasmic layer which in young nerves intervenes between the axis-cylinder nd the sheath of Schwann of a nerve-fibre, and in which the fatty substance of he medullary sheath becomes deposited.

Some observers have described a delicate structureless sheath around the axis-linder here as well as in ordinary nerves.

Nothing positive is known concerning the special purpose in the animal conomy which these curious appendages of the nerves are destined to fulfil. . Krause endeavours to show that the series of concentric capsules with terposed fluid is an arrangement for converting the effect of mechanical action into fluid pressure upon the nerve, so that tension and traction of the ssue in which the corpuscle is placed, may be felt and appreciated as ordinary ressure.

Little also is known as to their development, except that when first visible ey appear in the form of small agglomerations of cells amongst which the rmination of a nerve-fibre becomes lost to view.

End-bulbs.—If the conjunctiva of the calf or of certain other animals carefully spread out and examined under the microscope, many of the

medullated nerves which course in different directions in the membrane may be seen to end in very small oval or elongated corpuscles, into the interior of which the axis-cylinder of the nerve-fibre passes, surrounded by a soft homogeneous core, to end near the extremity of the corpuscle, with a rounded or dilated termination. The core with its contained fibre is inclosed in a simple nucleated capsule composed of flattened cells. The medullary sheath ceases abruptly at the entrance of the nerve, whereas the primitive sheath appears to be continued over the core, and to line the capsule. These so-called "cylindrical end-bulbs" were discovered by W. Krause, and they have been found not

Fig. 170.

Fig. 170.—CYLINDRICAL END-BULBS FROM THE CONJUNCTIVA OF THE CALF. (Merkel.)

A, in optical longitudinal section; B, in transverse section; *n*, entering nerve-fibre; *c*, nucleated capsule.

only in the conjunctiva of different animals, but in various parts of the skin and here and there in the mucous membrane of the mouth. Terminal corpuscles of this exact nature and form, have however hitherto not been observed in the conjunctiva of man nor of apes, but their place is here supplied by the small "spheroidal end-bulbs" of Krause (fig. 171, A). These (fig. 171, B, C) are composed of a connective tissue capsule (*a*) inclosing a number of polygonal cells, among which the axis-cylinder terminates. Sometimes the small medullated fibre which passes to each spheroidal end-bulb, divides into two or more branches before reaching the bulb, and the branches may be twisted around one another on their passage towards the organ (B). The capsule is continuous with the sheath of Henle of the nerve-fibre, and internally it is closely invested with a nucleated membrane, prolonged from the primitive sheath.

It will be seen that the so-called cylindrical end-bulbs closely resemble the central part or core of a Pacinian body divested of all but its innermost tunic, and, to complete the resemblance, flattened concentrically arranged cells are described by Merkel as occurring in the end-bulb as well as in the core of the Pacinian. In short, it would seem as if the little bodies in question represent the simplest of the type of terminal corpuscles of which the Pacinian corpuscles are the most complex examples; the complexity having been produced in the latter by the multiplication of the tunics. In conformity with this view it may be mentioned that Pacinian corpuscles are frequently found, especially in the lower animals, in which the tunics are few in number and the corpuscles correspondingly smaller. On the other hand, the round end-bulbs approach more nearly some of the tactile corpuscles in structure, those, namely, of a simple kind, such as are met with in birds, which form a transition to the much more complicated tactile corpuscles which occur in mammals, and especially those in the papillæ of the human hand. At the same time it cannot be supposed that there is any fundamental difference in the two kinds of end-bulb, although the arrangement of the

[illegible]ls in the core and the course taken by the nerve-fibre is seemingly different, [illegible]ce we see that in different animals those of the one kind are replaced by [illegible]se of the other kind.

Fig. 171.

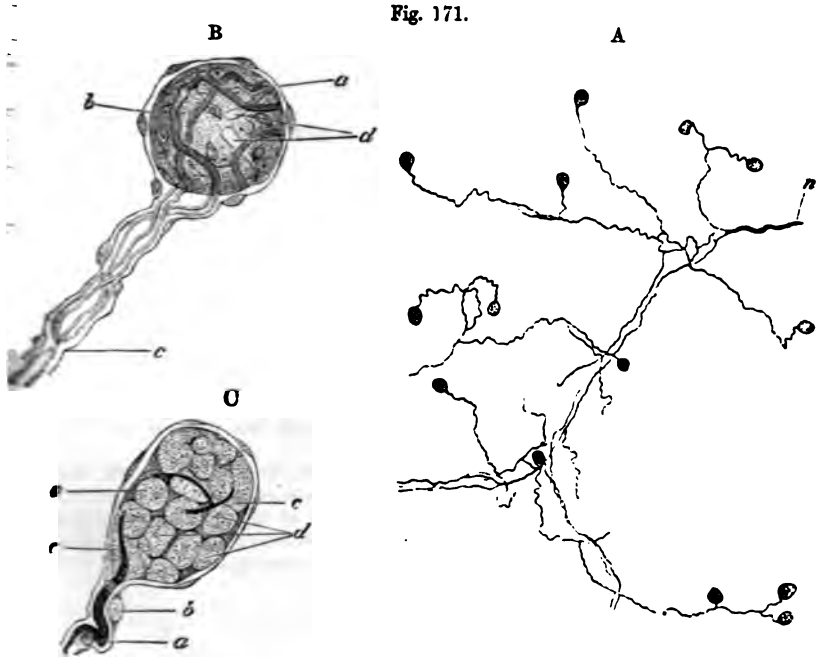


Fig. 171.—END-BULBS FROM THE HUMAN CONJUNCTIVA. (Longworth.)

A, Ramification of nerve-fibres in the mucous membrane, and their termination in end-bulbs, as seen with a lens; B, an end-bulb more highly magnified; *a*, nucleated capsule; *b*, core, the outlines of its component cells are not seen; *c*, entering fibre branching and its two divisions passing to terminate in the core at *d*; C, an end-bulb treated with osmic acid, showing the cells of the core better than B; *a*, the entering nerve-fibre; *b*, capsule with nuclei; *c*, *c*, portions of the nerve-fibre within the end-bulb, the ending of the fibre is not seen; *d*, *e*, cells of the core.

On account of the light which they throw upon the structure of the end-organs of mammals, a short description of the tactile end-organs of birds may not be out of place here.

Tactile corpuscles of birds.—It was noticed by Grandry that in the soft skin covering the bill of certain birds, such as the duck and goose, a peculiar form of end-organ exists consisting of two or more flattened cells, enclosed in a common capsule of connective tissue, and receiving between them the termination of the axis-cylinder (fig. 172). The structures in question have since been investigated by Merkel, Key and Retzius, Ranvier and Hesse, and more recently by Izquierdo, with the following results:—

The cells which form the corpuscle of Grandry are for the most part of no great thickness, and the surfaces which are opposed to one another are flattened. Their protoplasm is stated by Merkel to resemble that of nerve-cells, having a striated aspect, the striæ being partly concentric with the periphery of the cell, partly passing radially through it. The nucleus has also been compared to that of a ganglion-cell. There may be two only of these cells (which are termed by Merkel "tactile cells," by others "protective or inclosing cells") in a corpuscle of Grandry, or there may be three or four or even more, piled the one on the other. When numerous they may lose their regularity of arrangement. Occupy-

ing the interval between every two cells is a flattened disk termed the "tactile disk," and according to the testimony of all the above-named observers the axis-cylinder of the entering nerve-fibre ends in these tactile disks. According to Merkel, the disk is itself, on the other hand, directly in continuity with one or both of the cells between which it lies. The tactile cells and disks are all inclosed in a common capsule or sheath of connective tissue continuous with the perineurium of the nerve and receiving also a lining from the nucleated sheath of Schwann. From the capsule incomplete septa pass inwards between the flattened cells, as far as the edges of the tactile disks, so that the septa look as if they were perforated to receive the disks. Usually a single nerve-fibre passes to each corpuscle, and this may either lose its medullary sheath on entering the corpuscle or may retain it for some part of its course, although it eventually, in any case, becomes lost. The axis-cylinder, passing between the capsule and the tactile cells, divides into as many branches as there are tactile disks, in which, as already mentioned, it finally terminates.

It will appear from the above account that the chief point in which there is a difference of opinion with regard to the structure of these simply constructed tactile corpuscles, is as to the expansion of the axis-cylinder known as the tactile disk, whether this is prolonged or not into the cells which cover it. The former view is taken, as we have seen, by Merkel, but the opinions of most other observers are adverse to it. There is, however, this to be said in favour of Merkel's view, namely, that when degeneration takes place as a result of the section of the nerve, the degenerative process extends not only to the tactile disk but also to the cells which cover it.

These corpuscles are developed as a result of the multiplication and downgrowth of some of the epithelium-cells which lie at the apex of a papilla (fig. 172, c). The growth becomes entirely cut off from the rest of the epithelium and surrounded by connective tissue, whilst the cells in it are converted into the flattened "tactile cells," and a prolongation of a nerve-fibre grows up into it.

Fig. 172.

Fig. 172.—TACTILE CORPUSCLES FROM THE DUCK'S TONGUE. (Izquierdo.)

A, composed of three cells, with two interposed disks, into which the axis-cylinder of the nerve, *n*, is observed to pass; in B there is but one tactile disk enclosed between two tactile cells; C illustrates the development of a tactile corpuscle like the one shown in B; *e*, deeper cells of the epithelium covering the papillated surface of the tongue; *p*, apex of a papilla, in which there is seen to be a downgrowth of epithelium-cells, the lowermost of which are developed into tactile cells.

Other modes of ending of sensory nerves. Instead of ending in the special terminal corpuscles of different kinds which have been described in the preceding pages, many sensory nerves, as before stated, terminate in the form of fine ramifications of the axis-cylinder, which pass between the elements of the tissue to which the nerves are distributed, and may either simply come in contact with them, or, it is believed, may in some cases form an actual connection with the cells. As they approach their termination the sensory nerve-fibres, which are generally medullated, divide

dichotomously again and again, retaining after all the earlier divisions both the medullary sheath and the primitive sheath, and being accompanied by a prolongation of the sheath of Henle. Lower down this last-named sheath becomes lost, and a short distance further on the medullary sheath also disappears, the nerves being continued as pale fibres inclosed only by the nucleated sheath of Schwann. Within this it can distinctly

Fig. 173.

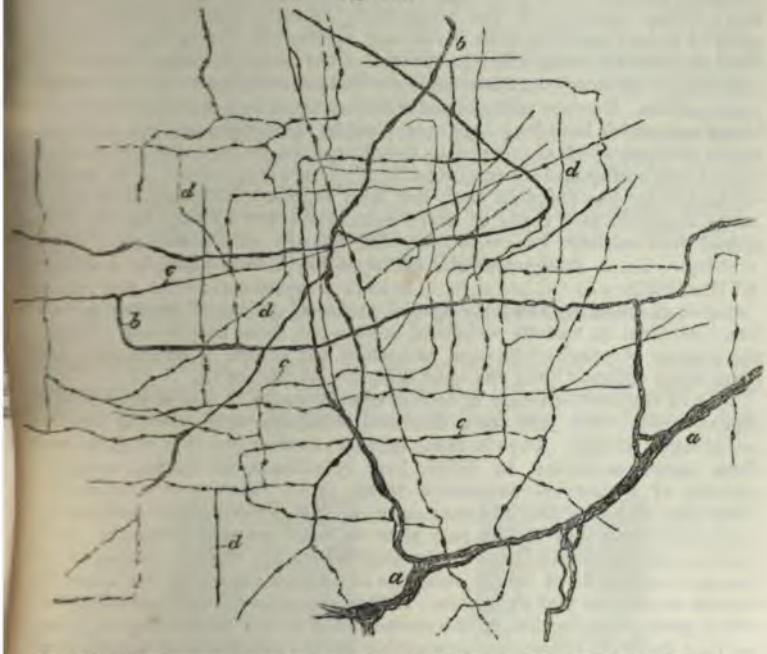


Fig. 173.—Distribution of nerves in a portion of the cornea of a frog. (Klein.)

The nerves are stained with chloride of gold. *a*, *a*, part of a plexus of non-medullated fibres, made up of numerous fine fibrils; *b*, *b*, smaller fibres derived from them, and themselves giving off still smaller branches, *c*, *c*, which are composed of single fibrils.

be seen in preparations stained with chloride of gold, that the axis-cylinder is made up of fine varicose fibrils (fig. 173, *a*, *a*). At every division of the nerve some of these fibrils pass into each branch, and where, as often happens, the branches unite with one another so as to form a subterminal plexus, some of the fibrils pass across from one branch to another. By the time the terminal ramification is reached many of the branches may consist of only one or two ultimate fibrils (*c*, *c*). It is generally found that the sheath of Schwann has ceased long before this condition is arrived at, although nuclei apparently like those of that sheath may often be still seen here and there upon the branches, especially at the points of bifurcation. Finally, the branches of the nerve, thus reduced to the condition of ultimate fibrils, often varicose, pass between the tissue elements, and may there form an actual network by joining one with another and becoming fused together at the points of junction, or may

end either simply or with small knobbed extremities without uniting with other fibrils into a nervous network ; or, according to the view of some histologists, may pass into the cells of the tissue and thus terminate.

A " nervous network " is not to be confounded with a " nervous plexus." In the former an actual fusion of the ultimate fibrillæ which result from the division of the axis-cylinders of the nerves is assumed to take place, whereas in the latter, although there may appear to be an intimate union between the different nerves which enter into the plexus, this union does not extend to the ultimate elements of the nerve-fibre ; in other words, although fibres or parts of fibres (fibrils) may be given and received by the several nerves to and from one another, these fibres (in the case of the larger plexuses) or fibrils (in the microscopic plexuses) remain completely distinct, although they may run in close juxtaposition. Nervous plexuses are of very common occurrence, both those of the larger sort which have long been recognized by anatomists, and the smaller microscopic plexuses which are very often found near the endings, both of some centripetally conducting, and of some centrifugally conducting nerves. But nervous networks are far less frequent than has been supposed, although they were until lately described as a mode of nerve-termination not by any means rare, and indeed their existence is now doubted altogether by some histologists. (Compare *Waldeyer*, Ue. d. Endigungsweise der sensiblen Nerven : Archiv f. mikr. Anat. XVII. s. 367.)

Nerve-endings in tendon.—Special modes of ending of sensory nerves have been described in various peripheral organs, but those only which are found in the tendons of muscles will here be noticed, the modes of termination in other parts being deferred until the several organs are treated of.

Most of the nerve-endings in tendon seem referable to one or other of the end-organs which have just been described, although they present considerable modification of form. Thus in many tendons, at their junction with the muscles, there occur, according to Golgi, long spindle-shaped bodies, composed apparently of a modified connective tissue, into which one or more medullated fibres pass, and after dividing once or twice diverge towards the periphery of the corpuscle, where they end as pale fibres in small granular swellings. In other tendons end-bulbs like those in the conjunctiva are found (Sachs), and small Pacinian corpuscles of simple structure occur occasionally in the areolar tissue sheaths of tendons and ligaments. Rollett describes the non-medullated nerves which pass to the tendon of the sterno-radial muscle in the frog as ending in peculiar flattened end-organs comparable to the end-plates of muscle presently to be described.

Lastly, some observers have described the nerves of tendons as ending, in part at least, in the form of ramifying pencils of pale fibres, usually varicose, and terminating freely, by fine tapering extremities, between the tendon bundles. This is similar to the way in which the nerves appear to end in the substantia propria of the cornea, which is also a form of fibrous tissue and receives a large number of nerve-fibres. But a detailed description of the manner in which the nerves of the cornea are distributed will be more conveniently deferred until the eye is treated of.

TERMINATIONS OF MOTOR NERVES.

In the **involuntary muscles** such as those which constitute the muscular layers of the hollow viscera, the nerves, which are for the most part non-medullated with a small intermixture of white fibres, form complicated plexuses as they near their termination. At the junctions of the fine nervous cords which compose the plexuses groups of ganglion-cells are in many parts met with ; a well known example of such a gangliated plexus being the *plexus myentericus* of Auerbach between the longitudinal and circular layers of the muscular coat of the intestine. From these gangliated plexuses branches are sent off, which penetrate between the elements

the sarcolemma (Kühne, fig. 174, *s*). Ranvier states, however, that it is a prolongation of the nucleated sheath of Henle, and not the primitive sheath which is continuous with the sarcolemma. The axis-cylinder as it passes into the fibre forms a clear localised branched expansion (*p p*), which lies immediately under the sarcolemma, embedded in a layer of granular matter which contains a number of large clear nuclei, each having one or more bright nucleoli. The termination of the axis-

Fig. 175.

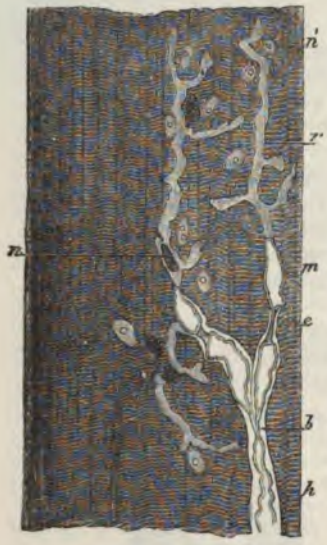


Fig. 175.—TERMINATION OF A NERVE IN A MUSCULAR FIBRE OF THE LIZARD (Lacerta viridis) (Ranvier.). Very highly magnified.

h, outer sheath of the nerve-fibre (sheath of Henle, according to Ranvier); *b*, bifurcation of the fibre; *e*, node; *m*, short segment beyond the node; *r*, terminal ramifications of the axis-cylinder; *n*, nuclei on the branches of the axis-cylinder; *n'*, nuclei in the granular substance of the end-plate. The granular substance lies in the intervals between the branches of the axis-cylinder; it is not seen in this figure.

cylinder is not in the form of a continuous plate, as was thought by Rouget, but appears when viewed from the surface in the form of an arborescent figure (fig. 175), the branches of which do not, according to Ranvier, anastomose. Attached to these branches small granular nuclei (*n*) are seen at intervals; these are not to be confounded with the clear nuclei of the granular substance (*n'*), nor with certain flattened nuclei which lie immediately under the sarcolemma covering the end-plate, and which resemble the nuclei of the nerve-sheath. The sarcolemma over the situation of the nerve-ending is slightly raised above the general surface (fig. 174 *a*). It would appear that a muscular fibre, when short, has but one terminal structure, and receives consequently but one nerve-fibre. As, moreover, the fibres of a nerve undergo division, probably repeated division, before ending, it follows that one fibre in a nerve-root or -trunk may supply several muscular fibres. Longer muscular fibres have two or more nerve-endings.

In amphibia (fig. 176) there is no granular substance with clear nuclei imbedded in it, and the ramifications of the axis-cylinder are extended over a larger proportionate area of the fibre than in scaly reptiles, birds, and mammals, so that the termination of the nerve is less localised. The branches of the axis-cylinder run for a short distance parallel with the axis of the fibre between the sarcolemma and muscular substance, terminating abruptly by rounded extremities. They present here and there slight enlargements, connected with which are seen, as in the end-plate of the lizard, granular pear-shaped nuclei (*b*), entirely different in appearance from the proper nuclei of the muscle (*e*). A fine tortuous fibril is stated by Kühne to be given off from the pale fibre to each of these granular nuclei, and to terminate in it by a bulbous enlargement.

It would appear then that in all classes of vertebrates the nerve-fibres

DEVELOPMENT OF NERVES.

It has been shown by Balfour in elasmobranch fishes, and by Milnes Marshall in the chick, and the same is probably the case in mammals, that the nerve-roots and their ganglia, and in all probability the nerves generally, develope as cell-outgrowths from the rudimentary central nervous system. The latter, as has long been known, is formed by an involution of the ectoderm or epiblast along the middle line of the embryo. So that not only the nerve-cells and -fibres of the central nervous system (brain and spinal cord), but also the peripheral nerves, and the nerve-cells of the ganglia in connection with them, are of ectodermal origin. No doubt the connective tissue which enters into the construction of the nerves and nerve-centres, as well as the blood-vessels which are distributed in them, are mesodermal, having become formed as ingrowths from the surrounding mesoderm, but it is as yet uncertain whether this statement holds good with regard to the substance (*neuroglia* of Virchow, *reticulum* of Kölliker) which occupies the interstices between the proper nervous elements within the nerve-centres. For according to Kühne and Ewald this substance exhibits so marked a resistance to the action of tryptic digestive fluids as to be comparable only to horny substance, and it is accordingly termed by them neuro-keratin. And since horny matter is not found except in connection with epithelial tissues, it is inferred by them that the neuro-keratin must be developed from some of the ectoderm-cells rather than from the included mesoderm. However this may be, it seems at least to be definitely ascertained that the nerve-cells in the nervous centres are derived from the ectoderm-cells which, undergoing enlargement and modification, both in their substance and form, send out branches at one or more points of their surface, and acquire the specific characters of nerve-cells.

But with reference to the formation of the nerve-fibres, both within the nervous centres and in the peripheral nerves, the knowledge as yet acquired is not very positive or consistent. It appears, however, to be certain that their development in both situations proceeds distalwards, and that the medullated fibres are originally formed as pale fibres, and only later acquire their medullary sheath. This change occurs, not simultaneously over the whole nervous system, but in regular order along definite tracts, and the knowledge of this, in the hands of Flechsig, has proved an important means of tracing the course of certain strands of fibres in the nervous centres, as will be noticed when the subject of the continuity of the fibres in those centres is dealt with.

According to the view which has generally been taken, nerve-fibres are formed by the linear coalescence of elongated cells, in the peripheral parts of whose protoplasm the fatty matter of the medullary sheath gradually accumulates, at first in the form of fine granules, and thus transforms the originally pale fibres into dark bordered fibres. This change of aspect is apparent in many nerves of the human embryo of the fourth or fifth month. According to Kölliker's account, the nerve-fibres in the tadpole's tail are prolonged by lines of fusiform cells, which coalesce into pale fibres. These send out fine offshoots, which may join with neighbouring fibres, or with branched cells, which become fibres, and in both of these ways the growth and branching of the nerves go on. The first fibres thus generated (embryonic fibres) virtually represent bundles of two, three, or more permanent fibres, into which they are speedily converted by cleavage; while the formation of the medullary sheath proceeds outwards along the branches.

But if, as seems to be the case, when a nerve has been cut and has undergone degeneration, the axis-cylinders are reproduced along the whole length of the distal part by a downgrowth from the axis-cylinders of the central cut end, it is probable that a similar mode of formation of the nerves may occur originally, and that the axis-cylinder is to be regarded as a continuous outgrowth from one of the nerve-cells of the nervous centre. With the medullary sheath, however, the case may be different. For this, as we have seen, is divided at regular intervals into a series of internodes, each of which possesses a nucleus, and may therefore, as Ranvier pointed out, be looked upon as representing a cell, the primitive sheath being homologous to the cell-membrane. It is not improbable, therefore, that each such internode is actually formed from an elongated

developed around a previously formed axial fibre, and filled with the y matter of the medullary sheath in the same way as the connective tissue- s become filled with fat in the development of the adipose tissue. In port of this view it may be noted that in young nerves the segments are rter than in the adult, and there is a layer of homogeneous or finely granular toplasmic substance outside the medullary sheath, between it and the primi- e sheath: as the nerves increase in size this layer, being more and more roached upon by fatty substance, eventually disappears, except in the immediate ghbourhood of the nuclei. In the brain and spinal cord at an early period of elopment flattened cells are said by Ranvier to be applied to the medullated es, but they subsequently disappear or become incorporated with the interstitial ue of those organs.

The fact that the nerve-segments of the peripheral nerves are considerably rter in the young animal, points to the existence of an interstitial as well as a minal growth of nerve-fibres.

Degeneration and regeneration of nerves.—The divided ends of a nerve t has been cut across readily reunite by cicatricial tissue, but the cut ends the fibres themselves do not thus unite. On the contrary, soon after the tion, a process of degeneration begins in the peripheral or severed portion of e nerve. The nuclei become multiplied, and the protoplasm about them largely reased in amount, the segments taking on to some extent their embryonic ndition. At the same time the medulla of the white fibres degenerates into a anular mass consisting of fatty molecules, and is then totally removed, and entually the axial fibre also disappears (fig. 177, A, B, & C).

In regeneration the new fibres grow afresh from the axial fibres of the central nd of the divided nerve-trunk (often more than one from each); and, pene- rating into the peripheral end of the trunk, grow along this as the axis-cylinders f the new nerves, becoming after a time surrounded with medullary substance (fig. 177, D).

To this brief summary the following details may be added:—In warm-blooded animals the first changes in the peripheral part of the nerve are seen twenty-four hours after the section. The nuclei underneath the primitive sheath are everywhere found hypertrophied, the primitive sheath is distinctly visible, and protoplasm is found to have accumulated at the expense of the medullary sheath, both in the immediate neighbourhood of the nuclei, at the nodes, and also at other points in the fibre, which correspond, according to Ranvier, with the intervals between the medullary segments. Fifty hours after the section in the rabbit (but not till four days in the dog) the protoplasmic aggregations are found here and there altogether to interrupt the continuity of the medullary sheath, and they contain numerous fatty granules, and sometimes droplets of myelin (fig. 177, A). About the fourth day the nuclei are seen to be multiplied, but not to any great extent (C); and the whole of the myelin after four or five days is broken up into drops, some larger, some smaller. The axis-cylinder is also found to be interrupted at numerous places, and remains only in the shape of short fibres, often curled round at their broken ends, enclosed in the large drops of myelin (B). Eventually these portions also may disappear. The myelin at length becomes almost entirely removed, until nothing remains of it except a few isolated drops, which escape absorption, and all that then remains of the original fibre is the primitive sheath, which is occupied by a protoplasmic mass containing an increased number of nuclei. During the disappearance of the myelin from the nerve-fibres the cells of the connective tissue in the neighbourhood of the fibres become charged with fatty granules, which may have become formed from the dissolved fatty substances of the medullary sheath.

These degenerative changes seem to occur simultaneously along the whole length of the nerve. In the nerves to voluntary muscles the end-plate is said, however, to be the part first affected.

In the immediate neighbourhood of the section the appearances are somewhat modified by the escape of the myelin from the cut ends of the nerve-fibre, and the infiltration of blood and lymph into the interior of the ends thus emptied of their contents. This change must of course occur both in the central stump of the nerve as well as in the peripheral cut end: it does not often extend beyond the

first node. Apart from such traumatic modification, true degenerative change not according to Ranvier occur in the end of the nerve which is still in connec with the centre, although proliferation of the nucleus in the first and second int

Fig. 177.

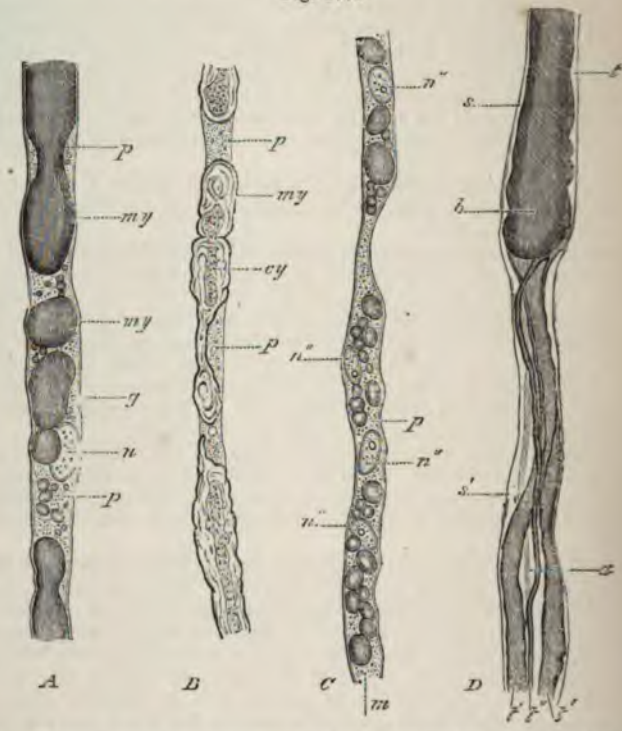


Fig. 177.—Degeneration and regeneration of nerve-fibres in the rabbit (Ranvier).

A, Part of a nerve-fibre in which degeneration is commencing in consequence of section (50 hours previously) of the trunk of the nerve higher up; *my*, medullary sheath becoming broken up into drops of myelin; *p*, granular protoplasmic substance which is replacing the myelin; *n*, nucleus, not yet multiplied; *g*, primitive sheath. B, another nerve-fibre in which degeneration is proceeding, the nerve having been cut four days previously. This specimen is differently prepared from the others, so as to exhibit the axis-cylinder (*cy*) also partly broken up into portions of different length, enclosed in the myelin, *my*. C, more advanced stage of degeneration, the medullary sheath having in great measure disappeared, while several nuclei (n'', n''') have been formed by division of the single nucleus of the internode. D, commencing regeneration of a nerve-fibre. Several small nerve-fibres (t', t'') have sprouted out from the enlarged cut end (*b*) of the nerve-fibre (*t*); *a*, an axis-cylinder, which has not yet acquired a medullary sheath; *s*, *s'*, primitive sheath.

nodes near the cut may take place. The central cut end of the axis-cylinder does not become altered; except that it undergoes a slight swelling, preparatory in all probability to the renewed growth by which the regeneration of the fibre is effected.

Regeneration proceeds but slowly. Up to the twenty-eighth day after the section, or even later than this, there is still no trace of new nerve-fibres in the peripheral part of the nerve. With the exception of a few fibres which for some reason not well understood (probably because they are derived from some other nerve which has not been cut, and are merely taking a recurrent course in the cut nerve), have not undergone degeneration, nothing is to be seen in a section of the nerve at this period, except the primitive sheaths of the old fibres, filled

h clear or finely granular substance. If, however, a transverse section be e of a nerve considerably later than this (sixty or seventy days after the inal section) it is found that within the tubes formed by the old primitive aths, and also in some places between them, small single fibres or groups of es, either pale or provided with a medullary sheath, are to be seen, besides e and there those drops of myelin which have remained unabsorbed from the dullary sheaths of the original fibres. On cutting out the central end of the ve, together with the cicatrix, and separating its fibres, it is seen that the ups of small fibres noticed in the transverse section are continuous with the tral ends of the axis-cylinders of the original nerve (fig. 177, D). Either a ch of small fibres may grow directly from the axis-cylinder of one fibre, or only may emerge from this; but these soon bifurcate, and, repeating this cess again and again, may eventually form a considerable group. It would ear therefore that the regeneration of a cut nerve is effected by a growth of fibres from the axis-cylinders of the central cut end, and that many more h fibres are formed in the first instance than the old ones which have under- e degeneration. The growth from the old axis-cylinders always occurs in the ation of a node—either the one nearest to the section or one somewhat higher

The new fibres are at first pale but subsequently acquire a medullary sheath, h constrictions of Ranvier, which, as in young nerves, are placed at much more quent intervals than in the old fibres, so that the intervals are much shorter. he groups of fibres which grow thus in groups from the old axis-cylinders are en very irregular in their course, twisting around one another, and even loop- back in some places for a considerable distance. In the cicatrix especially is s irregularity and obliquity of disposition noticeable, probably on account of e absence here of the guide formed by the sheaths of the original fibres.

Restoration of function in the nerve does not occur for several months, during hich time it may be presumed the new nerve-fibres are slowly finding their way ong the course of those which have been destroyed as a result of the section. f the numerous fibres in the groups above described, no doubt a few only even- ally assume the function of the fibres which they replace, but the later steps f the process of regeneration have not yet been fully followed out.

Except at the actual place of section the connective-tissue sheaths of the erves remain unaltered. In the cicatrix the new nerve-fibres do not at first run n definite sheaths, but these become subsequently developed from the connective- issue around, so that at length the restoration of continuity of all the structures n the nerve becomes complete.

Ranvier looks upon the regeneration of a nerve by growth from the intact central ends of the fibres as illustrating the tendency which, he believes, all nerve fibres exhibit, to grow continuously until a hindrance is met with, and he com- pares the result of cutting a nerve-fibre in causing the growth of a number of new fibres in place of the original one, to that produced when the leading shoot of a plant is removed, in causing the production of a number of lateral buds.

Some have thought that under favourable circumstances an immediate union between the ends of the nerve-fibres may happen after section; but considering he impossibility of procuring exact apposition of the individual fibres, end to end, s well as the inevitable extension of the effects of the mechanical injury aused by the section along the soft contents of the primitive sheath, it seems nprobable that such direct union should occur.

The degeneration does not affect, as we have seen, the part of the nerve remain- g in connection with the nervous centre, which seems to exert an influence in aintaining the nutrition of the nerve. The ganglia, as well as the grey matter the brain and spinal cord, are centres of this influence. It is found that, in the ntral portion of a divided spinal nerve, while the fibres belonging to the anterior ot owe their integrity to their connection with the spinal cord (and especially th the large cells of the anterior cornu), those of the posterior root are similarly pendent on the ganglion; and that, if the posterior root be cut between the nglion and the spinal cord, not only will the fibres which pass from it into e trunk of the nerve beyond the ganglion remain unchanged, but also those ove the ganglion, in the portion of the root left in connection with it; whereas e fibres of the same root which remain connected with the cord but severed

from the ganglion degenerate. Section of the sympathetic nerve in the neck followed by degeneration of the upper segment as high as the superior cervical ganglion, but no further.

The degeneration of the peripheral end of a cut nerve and the breaking up of the substance of the medullary sheath were first noticed by Nasse in 1839. In the discovery by Augustus Waller in 1852 of the dependence of the process upon isolation of the nerve-fibre from its nutritive centre, and his application of this discovery to the tracing the course of nerve-fibres in peripheral parts (now known as the Wallerian method) first gave full interest and importance to the observation of Nasse. The result has been the appearance of numerous writings upon the subject, the latest being those of Ranvier, whose account has been closely followed in the text.*

Recent Literature of the Nervous Tissues.—On the Structure of Nerves, &c.—*Frommann*, in Virch. Arch. 1864 & 1865 ; *Beale*, in Arch. of Medicine, 1865 ; *Deiters*, Ue. Gehirn u. Ruckenmark, 1865 ; *Courvoisier*, in Arch. f. mikr. Anat. II., 1866 ; *Kollmann u. Arnstein*, in Zeitschr. f. Biol. II., 1866 ; *M. Schultze*, Observationes, &c., Bonn, 1868 ; *Babuchin*, in Med. Centralbl., 1868 ; *S. Mayer*, Bau d. sympath. Nervenst., Wiener Sitzungsb., 1878 ; *Ranvier*, in Arch. de physiol., 1872 ; Tubes nerveux et T., Compt. rend. LXXI. ; and Leçons sur l'hist. du système nerv., 1878 ; *Gerlach*, Structur der grauen Substanz, Med. Centralbl., 1872 ; *Lantermann*, in Med. Centralbl., 1874, and Arch. f. mikr. Anat. XII., 1876 ; *Boll*, Hist. d. nerv. Centralorg., Arch. f. Psych., 1877 ; *McCarthy*, On spinal ganglia and nerve-fibres, Qu. J. of Micr. Sci., 1876 ; *Key & Retzius*, Studien in d. Anat. d. Nervensyst., &c., 1876 ; *H. D. Schmidt*, in Monthly Microsc. Journal, XI. ; *Kuhnt*, in Arch. f. mikr. Anat. XIII., 1876 ; *Ewald u. Kühne*, Ue. einem neuen Bestandth. d. Nervensyst., Heidelb. Verhandl., I. 1877 ; *Rumpf*, in Heidelberg Unters., II., 1878 ; *Frend*, Ue. Spinalgangl. d. Petromyzon, Wiener Sitzungsb., 1878 ; *H. Schultze*, in Arch. f. Anat. (u. Phys.), 1878 ; *Hesse*, in Arch. f. Anat. (u. Phys.), 1878 ; *Koch*, Dissert., Erlangen, 1879 ; *G. Retzius*, On nerve-cells of spinal ganglia, in Nord. med. Ark., 1880 ; *Rawitz*, Bau der Spinalganglien, Arch. f. mikr. Anat. 1880 ; and die Ranvier'sche Einschnurungen, &c., Arch. f. Anat. (u. Phys.), 1879 ; *Stricker u. Unger*, in Wiener Sitzungsb., 1879 ; *Engelmann*, Discontinuität d. Axencylinders, Pflüger's Arch. XXII., 1880 ; *Pertick*, in Arch. f. mikr. Anat., 1880.

On Development of Nerves.—*Hensen*, in Virch. Arch., XXX. & XXXI., 1864, and Arch. f. mikr. Anat. IV., 1868 ; *Eberth*, in Arch. f. mikr. Anat., II., 1866 ; *Rouget*, in Comptes rendus, LXXIX., 1873 ; *Flechsig*, Die Leitungsbahnen im Gehirn u. Ruckenmark, 1876 ; *Lebouco*, in Bull. d. l'acad. de Belgique, 1876.

On Degeneration and Regeneration of Nerves.—*Laveran*, in J. de l'anat., V. ; *E. Neumann*, in Arch. d. Heilkunde, IX. ; and Arch. f. mikr. Anat., XVIII., 1880 ; *Herz*, in Virch. Archiv, XLVI., 1869 ; *W. Krause*, in Arch. f. Anat., 1870 ; *Engelmann*, in Pfl. Arch., XIII., 1876 ; *Ranvier*, Leçons, 1878 ; and in Compt. rend., LXXVIII., 1879 ; *S. Mayer*, in Wiener Sitzungsb., 1878 ; *Rumpf*, in Heidelb. Unters., II., 1878.

On the Endings of Motor Nerves.—*Rouget*, in Comptes rendus, LV., 1862 ; LIX., 1864 ; *W. Krause*, several papers in Göttinger Nachr., Zeitschr. f. rat. Med., and Arch. f. Anat. ; and "Motor. Endplatten," 1869 ; *Kühne*, Periph. Endorg. d. motor. Nerven, 1862 ; various papers in Virch. Arch. ; and article in Stricker's Handb., 1871 ; *Waldeyer*, in Med. Centralbl., 1863 ; *Cohnheim*, in Virch. Arch., XXXIV., 1865 ; *J. Gerlach*, Verhältn. d. Nerven, &c., Leipzig, 1874 ; *Ranvier*, in Leçons. &c., 1878 ; *Schwalbe*, Gesetz des Muskel-nervenеintritts, Arch. f. Anat. (u. Phys.), 1879.

Nerves of Non-striated Muscle.—*Klebs*, in Med. Centralbl., 1863, and Virch. Arch., XXXII., 1864 ; *Frankenhausen*, in Med. Centralbl., 1866 ; *Tolotschinoff*, in Arch. f. mikr. Anat. V., 1869 ; *Arnold*, article "Organ. Muskeln," in Stricker's Handb., 1871 ; *Löwit*, in Wiener Sitzungsb., 1875.

A complete list of books and papers treating of the peripheral distribution and modes of termination of sensory nerves will be found in the work by Merkel "Ueber die Endigungen der sensiblen Nerven, &c.," Rostock, 1880. To the list there given may be added—*Krause*, in Arch. f. mikr. Anat. XIX., 1880, *Flemming* in same journal ; *Ranvier*, in Qu. J. Micr. Sci., 1880 (nerves in epidermis) ; and *Klein* in same journal (nerves of cornea). The following treat of the nerve-endings in tendon :—*C. Sachs*, in Arch. f. Anat., 1875 ; *Rollett*, in Wiener Sitzungsb., 1876 ; *Golgi*, in Atti. d. soc. di scienze nat. a Milano, XXI., 1879.

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* According to S. Mayer, degeneration of nerve-fibres, followed by their regeneration, is constantly found to occur as a normal process, without artificial severance from the nutritive centre. Mayer conceives that in this way the nerve-fibres throughout the body are continually being renewed.

BLOOD-VESSELS.

The blood, from which the solid textures immediately derive material their nourishment, is conveyed through the body by branched tubes ed blood-vessels. It is driven along these channels by the action the heart, which is a hollow muscular organ placed in the centre of sanguiferous system. One set of vessels, named *arteries*, conducts blood out from the heart and distributes it to the different regions the body, whilst other vessels named *veins* bring it back to the heart in. From the extreme branches of the arteries the blood gets into commencing branches of the veins or revehent vessels, by passing rough a set of very fine tubes which connect the two, and which, ough not abruptly or very definitely marked off from either, are erally spoken off as an intermediate set of vessels, and by reason of eir smallness are called the *capillary* (*i.e.*, hair-like) *vessels*, or, simply, e *capillaries*.

ARTERIES.

These vessels were originally supposed to contain air. This error, hich had long prevailed in the schools of medicine, was refuted by alen, who showed that the vessels called arteries, though for the ost part found empty after death, really contain blood in the living dy.

Mode of Distribution.—The arteries usually occupy protected uations; thus, after coming out of the great visceral cavities of the dy, they run along the limbs on the aspect of flexion, and not on that of extension where they would be more exposed to accidental ury.

As they proceed in their course the arteries divide into branches, and division may take place in different modes. An artery may at once olve itself into two or more branches, no one of which greatly exceeds rest in magnitude, or it may give off several branches in succesn and still maintain its character as a trunk. The branches come at different angles, most commonly so as to form an acute angle h the further part of the trunk, but sometimes a right or an obtuse gle, of which there are examples in the origin of the intercostal eries.

An artery, after a branch has gone off from it, is smaller than before, t usually continues uniform in diameter or cylindrical until the next ession; thus it was found by Hunter that the long carotid artery of camel does not diminish in calibre throughout its length. A branch an artery is less than the trunk from which it springs, but the comned area or collective capacity of all the branches into which an artery rides, is greater than the calibre of the parent vessel immediately above point of division. The increase in the joint capacity of the branches er that of the trunk is not in the same proportion in every instance division, and there is at least one case known in which there no enlargement, namely, the division of the aorta into the common ac and sacral arteries; still, notwithstanding this and other possible ceptions, it must be admitted as a general rule that an enlargement

of area takes place. From this it is plain that, since the area of the arterial system increases as its vessels divide, the capacity of the smallest vessels and capillaries will be greatest; and, as the same rule applies to the veins, it follows that the arterial and venous systems may be represented, as regards capacity, by two cones whose apices (truncated it is true) are at the heart, and whose bases are united in the capillary system. The effect of this must be to make the blood move more slowly as it advances along the arteries to the capillaries, like the current of a river when it flows in a wider and deeper channel, and to accelerate its speed as it returns from the capillaries to the venous trunks.

When arteries unite they are said to anastomose or inosculate. Anastomoses may occur in tolerably large arteries, as those of the brain, the hand and foot, and the mesentery, but they are much more frequent in the smaller vessels. Such inosculations admit of a free communication between the currents of blood, and must tend to promote equability of distribution and of pressure, and to obviate the effects of local interruption.

Arteries commonly pursue a tolerably straight course, but in some parts they are tortuous. Examples of this in the human body are afforded by the arteries of the lips and of the uterus, but more striking instances may be seen in some of the lower animals, as in the well-known case of the long and tortuous spermatic arteries of the ram and the bull. In very moveable parts like the lips, this tortuosity will allow the vessel to follow their motions without undue stretching; but in other cases its purpose is not clear. The physical effect of such a condition of the vessel on the blood flowing along it must be to reduce the velocity, by increasing the extent of surface over which the blood moves, and consequently the amount of impediment from friction; still it does not satisfactorily appear why such an end should be provided for in the several cases in which arteries are known to follow a tortuous course. The same remark applies to the peculiar arrangement of vessels named a "rete mirabile," where an artery suddenly divides into small anastomosing branches, which in many cases unite again to re-construct and continue the trunk. Of such *retia mirabilia* there are many examples in the lower animals, but, as already remarked, the purpose which they serve is not apparent. The best known instance is that named the *rete mirabile of Galen*, which is formed by the intracranial part of the internal carotid artery of the sheep and several other quadrupeds.

Arteries possess considerable strength and a very high degree of elasticity, being extensible and retractile both in their length and their width. When cut across they present, although empty, an open orifice; the veins, on the other hand, collapse, unless when prevented by connection with surrounding rigid parts.

Structure.—In most parts of the body the arteries are inclosed in a sheath formed of connective tissue, and their outer coat is connected to the sheath by filaments of the same tissue, but so loosely that, when the vessel is cut across, its ends readily shrink some way within the sheath. Some arteries want sheaths, as those for example which are situated within the cavity of the cranium.

Independently of this sheath, arteries (except those of minute size whose structure will be afterwards noticed with that of the capillaries)

ave been usually described as formed of three coats, named, from their elative position, internal, middle, and external (fig. 178, in section); nd as this nomenclature is generally followed in medical and surgical

Fig. 178.

Fig. 178.—TRANSVERSE SECTION OF PART OF THE WALL OF THE POSTERIOR TIBIAL ARTERY (MAN). 75 DIAMETERS. (E.A.S.)

a, Epithelial and subepithelial layers of inner coat; *b*, elastic layer (fenestrated membrane) of inner coat, appearing as a bright line in section; *c*, muscular layer (middle coat); *d*, outer coat, consisting of connective tissue bundles. In the interstices of the bundles are some connective tissue nuclei, and, especially near the muscular coat, a number of elastic fibres cut across.

works, and also correctly applies to the structure of arteries so far as it is discernible by the naked eye, it seems best to adhere to it as the basis of our description; although it will be seen, as we proceed, that some of these coats are found on microscopic examination really to consist of two or more strata differing from each other in texture, and therefore reckoned as so many distinct coats by some authorities.

Internal coat (*Tunica intima*) (fig. 178, *a*, *b*). This may be raised from the inner surface of the arteries as a fine transparent colourless membrane, elastic but very easily broken, especially in the circular or transverse direction, so that it cannot be stripped off in large pieces. It is very commonly corrugated with fine and close longitudinal wrinkles,

Fig. 179.

Fig. 179.—EPITHELIAL LAYER LINING THE POSTERIOR TIBIAL ARTERY OF MAN. 250 DIAMETERS. (E.A.S.)
Nitrate of silver preparation.

caused most probably by a contracted state of the artery after death. Such is the appearance presented by the internal coat to the naked eye, but by the aid of the microscope, it is found to consist of three different structures, namely:—

1. An *epithelial layer* (fig. 178, *a*, and fig. 179) forming the innermost part or lining. This is a simple layer of thin elliptical or irregularly polygonal cells, which are often lengthened into a lanceolate shape. The cells have round or oval nuclei, with nucleoli: their outlines are often indistinct in the fresh state, but may be brought into view by means of nitrate of silver.

2. A *subepithelial layer* (striated layer of Kölliker). This is composed of a finely fibrillated connective tissue with a number of branched corpuscles lying in the cell-spaces of the tissue (fig. 180). This layer is most developed in the larger arteries: it exists however in the medium-sized

Fig. 180.

Fig. 180.—Cell-spaces of subepithelial layer of artery (posterior tibial). 250 diameters. (E.A.S.)

The ground substance is stained by nitrate of silver, and the cell-spaces of the tissue are thus made manifest as white patches, the contained cells not being seen.

ones. In the aorta it is very well marked and contains a large number of anastomosing cells and cell-spaces lying on a finely fibrillated ground-substance. Moreover, longitudinal networks of very fine elastic fibres, which are in continuity with the larger elastic fibres of the next layer, occur in it in the aorta.

3. *Elastic layers* (fig. 178, *b*). These form the chief substance of the inner coat. The elastic tissue forms longitudinal networks of fibres (fig. 181), which consist of one or more layers of different degrees of closeness. Not uncommonly some of these (or one in particular)

Fig. 181.

Fig. 182.

Fig. 181.—Elastic network of artery. 250 diameters (Kölliker).

Fig. 182.—Portion of fenestrated membrane from the femoral artery, magnified 200 diameters (Henle).

a, *b*, *c*, perforations.

take on a membranous character, in which case the "perforated" or "fenestrated" membrane of Henle is formed. This consists of a thin and brittle transparent film of elastic tissue. It can be stripped off in small shreds, which have a remarkable tendency to curl in at their borders, and roll themselves up as represented in fig. 182. The films of membrane are marked by fine pale lines, following principally

longitudinal direction, and joining each other obliquely in a sort of network. These lines are reticulating fibres formed upon the membranous layer and continuous with the reticulating elastic fibres which pervade the muscular coat on the one side and with those which extend into the subepithelial layer on the other. The membrane is further remarkable by being perforated with numerous round, oval, or irregularly shaped apertures of different sizes. In some parts of the arteries the perforated membrane is very thin, and therefore difficult to strip off; in other situations it is of considerable thickness, consisting of several layers; in which case it tends in the outer layers to lose its membranous character: indeed it must be borne in mind that every transition is met with between the fenestrated membranes, and the longitudinal elastic network.

The inner coat may thus be said to be formed of (1) a layer of flattened epithelial cells, (2) a layer of delicate connective tissue with branched cells; and (3) of elastic tissue under two principal forms, namely, the longitudinal elastic networks and the fenestrated membrane; and these two forms may coexist in equal amount, or one may predominate, the other diminishing or even disappearing altogether.

Middle coat (*Tunica media*) (fig. 178, *c*). This consists of plain muscular tissue, in fine bundles, disposed circularly round the vessel, and consequently tearing off in a circular direction, although the individual bundles do not form complete rings. The considerable thickness of the walls of the larger arteries is due chiefly to this coat; and in the smaller

Fig. 183. Fig. 184.

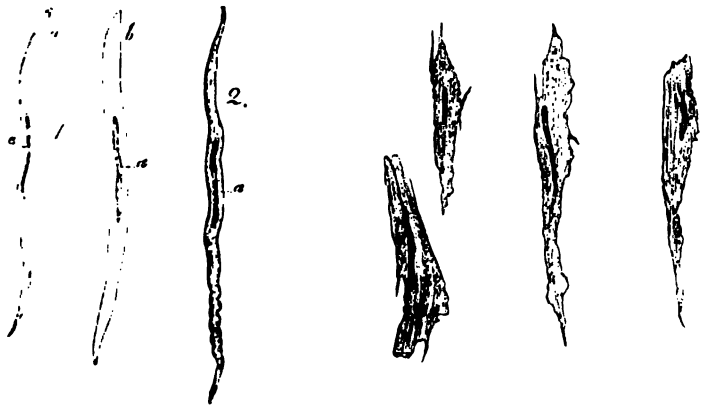


Fig. 183.—Muscular fibre-cells from human arteries. Magnified 350 diameters.

1. From the popliteal artery; *a*, natural; *b*, treated with acetic acid. 2, From a small branch of the posterior tibial (from Kölliker).

Fig. 184.—Muscular fibre-cells from superior thyroid artery (man). 340 diameters. (E.A.S.)

ones, it is said to be thicker in comparison with the calibre of the vessel. In the larger vessels it is made up of many layers; and elastic films either finely reticular, or quite similar to the fenestrated membrane of the inner coat, are found between the muscular layers alternating with them, and also being united with one another by elastic fibres passing between the muscular bundles. In most arteries this elastic tissue of the

middle coat is but slightly developed, but in the aorta (fig. 183) and carotid arteries and in some of the branches of the latter, it attains a considerable development, and since in them also elastic fibres are seen extending into the subepithelial layer of the inner coat, the distinction between the inner and middle coats as shown in section is far less marked than it is in ordinary arteries. The middle coat is of a tawny or reddish yellow colour, not unlike that of the elastic tissue, but, when quite fresh, it has a softer and more translucent aspect. Its internal part is often described as redder than the rest, but the deeper tint is probably due to staining by the blood after death.

The muscular fibre-cells of the middle coat of the arteries (fig. 183 and fig. 184) are seldom more than from $\frac{1}{300}$ to $\frac{1}{200}$ of an inch long and frequently, especially in those arteries in which the elastic tissue of the middle coat is most developed, present a very irregular shape with jagged extremities (fig. 184). Their nuclei are distinctly rod-shaped and are often slightly curved.

Bundles of white connective-tissue fibrils may also occur in small quantity in the middle coat, the proportion increasing with the size of the artery. It is important to note that the muscular tissue of the middle coat is more pure in the smaller arteries, and that the admixture of other tissues increases in the larger-sized vessels; in these, moreover, the muscular cells are smaller. Accordingly, the contractility of the arteries, which depends on their middle coat, is little marked in those of large size, but becomes much more conspicuous in the smaller branches.

External coat (*Tunica adventitia*) (fig. 178, *d*). This is composed mainly of fine and closely-felted bundles of white connective tissue, together with a variable amount of longitudinally disposed elastic tissue between the bundles (in the figure this is seen cut across). The latter is much more abundant towards the inner part, next the muscular coat, and is frequently described as constituting here a distinct elastic layer: it is most marked in arteries of medium calibre, becoming thinner, and at length gradually disappearing in those of small size.

In large and middle-sized arteries the bundles of white connective tissue chiefly run diagonally or obliquely round the vessel, and their interlacement becomes much more open and lax towards the surface of the artery, where they connect the vessel with its sheath or with other surrounding parts. Longitudinally arranged contractile fibre-cells have been described by various observers in the external coat of some of the larger arteries (especially the iliacs, superior mesenteric, splenic, renal and dorsalis penis, and in the umbilical arteries of the fœtus). In the umbilical arteries, according to Eberth, a complete layer of longitudinal muscular fibres is also present in the middle coat, internal to the ordinary circular fibres. Scattered longitudinal muscular cells are present in some arteries amongst the circularly disposed fibres of the middle coat, and even in the subepithelial layer of the internal coat. The outer coat is usually of greater proportionate thickness in the smaller arteries, but as it shades off into the surrounding connective tissue it is difficult to adjudge its exact thickness.

Some arteries have much thinner coats than the rest, in proportion to their calibre. This is strikingly the case with those contained within the cavity of the cranium, and in the vertebral canal; the difference depends on the external and middle coats, which in the vessels referred to are thinner than elsewhere.

Vessels and Nerves of Arteries.—The coats of arteries receive small vessels, both arterial and venous, named *vasa vasorum*, which serve for their nutrition. The little nutrient arteries are not derived immediately from the cavity of the main vessel but pass into its coats from branches which arise from the artery (or sometimes from a neighbouring artery), at some distance from the point where they are ultimately distributed, and divide into smaller branches within the sheath, and upon the surface of the vessel, before entering the outer coat where they are distributed. In some of the larger mammals, a few pass into the middle coat, and follow the circular course of its fibres, but in health none penetrate into this coat in the human subject and still less into the internal coat (Ranvier). Minute venules return the blood from these nutrient arteries, which, however, they do not closely accompany, and discharge it into the vein or pair of veins which usually runs alongside the artery. Lymphatics are present in the outer coat.

Arteries are generally accompanied by larger or smaller nerves; and when, in the operation of tying an artery, these happen to be included along with it in the ligature, pain is experienced; but the vessel itself, when in a healthy condition, is insensible. Nerves are, nevertheless, distributed to the coats of arteries. They form plexuses round the larger arteries, and run along the smaller branches in form of fine bundles of fibres, which here and there twist round the vessel, and unite with one another in a plexiform manner. The fine branches destined for the artery penetrate to the middle coat, to the muscular tissue of which they are chiefly distributed.

Minute ganglia are found in various parts connected with the arteries, but their existence does not appear to be by any means universal.

VEINS.

Mode of distribution.—The veins are ramified throughout the body, like the arteries, but in most regions and organs of the body they are more numerous and larger, so that the venous system is altogether more capacious than the arterial. The pulmonary veins form an exception to this rule, for they do not exceed in capacity the pulmonary arteries.

The veins are arranged in a superficial and a deep set, the former running immediately beneath the skin, and thence named subcutaneous, the latter usually accompanying the arteries, and named *venæ comites vel satellites arteriarum*. The large arteries have usually one accompanying vein, and the medium-sized and smaller arteries two, but there are exceptions to this rule. The veins within the skull and spinal canal, the hepatic veins, and the most considerable of those belonging to the bones, run apart from the arteries.

The communications or anastomoses between veins of considerable size, are more frequent than those of arteries of equal magnitude.

Structure.—The veins have much thinner coats than the arteries, and collapse when cut across or emptied; whereas a cut artery presents a patent orifice. But, notwithstanding their comparative thinness, the veins possess considerable strength, more even, according to some authorities, than arteries of the same calibre. The number of their coats has been differently reckoned, and the tissues composing them differently described by different writers, and this discrepancy of statement is perhaps partly due to the circumstance that all veins are not perfectly

alike in structure. In most veins of moderate size, three coats may be distinguished, which, as in the arteries, have been named external, middle, and internal.

Internal coat.—This is less brittle than that of the arteries, and therefore admits of being more readily peeled off without tearing; but, in other respects, the two are much alike. It consists of an *epithelium*, a *subepithelial connective tissue layer*, and an *elastic layer* (fig. 185, *a*, *b*).

The epithelium of the veins is similar in character to that of the arteries, but the cells are shorter and broader. The subepithelial layer is less developed in most veins than in the arteries, and indeed is absent altogether in many. It is better marked in some of the medium-sized veins than in the larger trunks. The elastic tissue of the inner coat occurs as dense lamelliform networks of longitudinal elastic fibres, and

Fig. 185.

Fig. 185.—TRANSVERSE SECTION OF PART OF THE WALL OF ONE OF THE POSTERIOR TIBIAL VEINS (MAN). (E. A. S.)

a, Epithelial and subepithelial layers of inner coat; *b*, elastic layers of inner coat; *c*, middle coat consisting of irregular layers of muscular tissue, alternating with connective tissue, and passing somewhat gradually into the outer connective tissue and elastic coat, *d*.

but seldom as fenestrated membranes. Longitudinal muscular bundles, as well as isolated contractile cells, are found in the inner coat of some veins.

Middle coat.—This tunic is thinner than that of the arteries, and has a much larger admixture of white connective tissue. It is pervaded by an elastic network, but this is even less conspicuous in the veins than in the arteries. In the veins of the limbs (especially the upper) and in those of some other parts, the muscular fibre-cells have for the most part as in the arteries a transverse direction, although the layer which they form is not everywhere complete, being separated into bundles by the intervention of connective tissue (fig. 185, *c*). But in many veins some of the innermost fibres of the middle coat take a longitudinal course. This is the case with the iliac, crural, branches of the mesenteric, umbilical of the fœtus, and other veins (Eberth).

In many of the larger veins the middle coat is less developed, especially as regards its muscular fibres, but in such cases the deficiency may be supplied by muscularity of the outer coat. The middle coat is wanting altogether in the thoracic part of the inferior vena cava, but is well marked in the hepatic part: in the part below the liver the muscularity of the middle coat is less marked. In the internal and external jugular veins there is but a slight development of the muscular tissue.

External coat (fig. 185, *d*).—This is often thicker than the middle

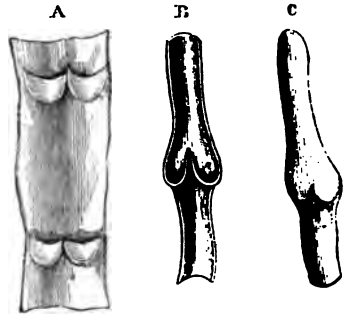
e line of junction between them is not sharply marked. It ɔnse areolar tissue and longitudinal elastic fibres. In certain ıs pointed out by Remak, this coat contains a considerable lain or non-striated muscular tissue. Thus the muscular well marked in the whole extent of the abdominal cava, y form a longitudinal network, occupying the inner part of coat; and they may be traced into the renal, azygos, d external iliac veins. The muscular tissue of the external ell developed in the trunks of the hepatic veins and in that ortæ, whence it extends into the splenic and superior mesen- found also in the axillary vein.

ıs present peculiarities of structure, especially in respect of as follows. 1. The striated muscular tissue of the auricles is prolonged for some way on the adjoining part of the venæ ılmonary veins. 2. The (plain) muscular tissue is largely the veins of the gravid uterus, in which, as well as in eins, it is described as being present in all three coats, and ɔr the most part a longitudinal arrangement. 3. On the muscular tissue is wanting in the following veins, viz., *a*, maternal part of the placenta; *b*, most of the veins of the ; the veins of the retina; *d*, the venous sinuses of the dura e cancellar veins of the bones; *f*, the venous spaces of the rnosa. In most of these cases the veins consist merely of m and a layer or layers of connective tissue more or less in the corpora cavernosa the epithelium is applied to the ssue. It may be added that in the thickness of their coats al veins surpass the deep, and the veins of the lower limbs upper.

s of the veins are supplied with nutrient vessels, *vasa* the same manner as those of the arteries. Nerves are to them in the same manner as to the arteries, but in far ıce.

–Most of the veins are th valves, a mechanical adapted to prevent the e blood. The valves are milunar folds of the in- strengthened by included

Fig. 186.



IAGRAM SHOWING VALVES OF VEINS.

a vein laid open and spread pairs of valves. B. Longitudi- a vein, showing the apposition of the valves in their closed tion of a distended vein, ex- lling in the situation of a pair

tissue, and projecting into the vein. Most commonly two r flaps are placed opposite each other (fig. 186, A); the ler of each (which, according to Haller, forms a parabolic nnected with the side of the vein; the other edge is free, owards the heart, or at least in the natural direction of the he blood along the vessel, and the two flaps incline obliquely

towards each other in this direction. Moreover the wall of the vein immediately on the cardiac side of the curved line of attachment of the valves, is dilated into a pouch or *sinus* (fig. 186, B), so that when distended with blood or by artificial injection, the vessel bulges out on each side, and thus gives rise to the appearance of a knot or swelling wherever a valve is placed (as in fig. 186, C). From the above description, it is plain that the valves are so directed as to offer no obstacle to the blood in its onward flow, but that, when from pressure or any other cause it is driven backwards, the refluent blood, getting between the dilated wall of the vein and the flaps of the valve, will press them inwards until their edges meet in the middle of the channel and close it up.

The epithelium-cells differ in shape and arrangement upon the two surfaces of the valves. On the side which faces inwards, and past which the current of blood flows, the cells are elongated in the direction of the current, whereas upon the opposite side which, when the valves are thrown back, faces the wall of the vein, the cells are elongated transversely. The main substance of the valve is formed by bundles of connective tissue, which have for the most part a transverse arrangement, and between which a few elastic fibres are seen. The tissue is covered on each surface by a prolongation of the inner coat of the vein, the covering being much thicker on the inner than on the outer surface. The valve is thinner close to its attachment than elsewhere. At its base a few transverse muscular fibres are sometimes seen, prolonged into it from the middle coat.

The valvular folds are usually placed in pairs as above described; in the veins of the horse and other large quadrupeds three are sometimes found ranged round the inside of the vessel; but this rarely occurs in the human body. On the other hand, the folds are placed singly in some of the smaller veins, and in large veins single valvular folds are not unfrequently placed over the openings of smaller entering branches; also in the right auricular sinus of the heart there is a single crescentic fold at the orifice of the vena cava inferior, and another more completely covering the opening of the principal coronary vein.

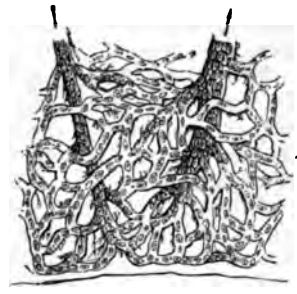
Many veins are destitute of valves. Those which measure less than $\frac{1}{12}$th of an inch (about 2 millimeters) in diameter rarely, if ever, have them. In man, valves are wanting in the superior and inferior venæ cavæ, in the trunk and branches of the portal vein, in the hepatic, renal, and uterine veins; also in the spermatic (ovarian) veins of the female. In the male, these last-mentioned veins have valves in their course, and in each sex a little valve is occasionally found in the renal vein, placed over the entrance of the spermatic. The pulmonary veins, those within the cranium and vertebral canal, and those of the cancellated texture of bone, as well as the trunk and branches of the umbilical vein, are also without valves. In the azygos and intercostal veins valves are not generally found, and when present are few in number. On the other hand, they are numerous in the veins of the limbs (and especially of the lower limbs), which are much exposed to pressure in the muscular movements or from other causes, and have often to support the blood against the direction of gravity. No valves are met with in the veins of reptiles and fishes, and not many in those of birds.

SMALLER ARTERIES AND VEINS AND CAPILLARIES.

That the blood passes from the extreme arteries into the veins was a necessary part of the doctrine of the circulation, as demonstrated by Harvey, in 1628; but the mode in which the passage takes place was not ascertained until some time after the date of his great discovery. The finding of the capillary vessels, and of the course of the blood

igh them, was in fact one of the first fruits of the use of the micro-
in anatomy and physiology, and was reserved for Malpighi (in 1661).
hen the web of a frog's foot is viewed through a microscope of
rate power (as in fig. 187), the blood is seen passing rapidly along
mall arteries, and thence more slowly
igh a network of finer channels, by
h it is conducted into the veins.
e small vessels interposed between the
t branches of the arteries and the

Fig. 187.



187.—CAPILLARY BLOOD-VESSELS IN THE WEB A FROG'S FOOT, AS SEEN WITH THE MICROSCOPE ter Allen Thomson).

he arrows indicate the course of the blood.

mencing veins, are the capillary vessels.
course of the blood in them may be
veniently seen also in the lungs or
entery of the frog, in the external gills
tail of tadpoles; in the tail of small fishes; in the mesentery of
ll quadrupeds; and generally, in short, in the transparent vascular
s of animals which can be brought under the microscope. These
els can also be demonstrated by means of fine injections of coloured
erial, not only in membranous parts, such as those above mentioned,
also in more thick and opaque tissues, which can be subsequently
ered transparent.

he capillary vessels of a part are most commonly arranged in a net-
, the branches of which are of nearly uniform size, though not all
tly equal; and thus they do not divide into smaller branches like
rteries, or unite into larger ones like the veins; but the diameter of
ubes, as well as the shape and size of the reticular meshes which
form, differs in different textures. Their prevalent size in the
an body may, speaking generally, be stated at from $\frac{1}{3500}$ to $\frac{1}{2000}$ of
ch, as measured when naturally filled with blood. But they are
to be in some parts considerably smaller, and in others larger than
standard: thus, Weber measured injected capillaries in the brain,
h he found to be not wider than $\frac{1}{4700}$ of an inch, and Henle has
ved some still smaller,—in both cases apparently smaller than the
al diameter of the blood-corpuscles. The capillaries, however, when
ved of blood, probably shrink in calibre immediately after death;
this consideration, together with the fact that their distension by
cial injection may exceed or fall short of what is natural, should make
sitate on such evidence to admit the existence of vessels incapable
rmitting the red corpuscles of the blood easily to pass through them.
diameter of the capillaries of the marrow of the bones is stated
$\frac{1}{1200}$ of an inch. In other parts, their size varies between the
mes mentioned: it is small in the lungs, and in muscle; larger in
kin and mucous membranes. The extreme branches of the arteries
eins in certain parts of the synovial membranes are connected by
lary loops, which are considerably dilated at their point of flexure,
dilatations are also found upon the transverse capillaries of the red
les of the rabbit.

here are differences also in the size or width of the meshes of the

capillary network in different parts, and consequently in the number of vessels distributed in a given space, and the amount of blood supplied to the tissue. The network is very close in the lungs and in the choroid coat of the eye, and comparatively close in muscle, in fat, in the skin, and in most mucous membranes, also in glands and secreting structures, and in the grey part of the brain and spinal cord. On the other hand, it has wide meshes and comparatively few vessels in the ligaments, tendons, and other allied textures. In infants and young persons, the tissues are comparatively more vascular than in after-life.

The figure of the capillary network is not the same in all textures. In many cases the shape of the meshes seems accommodated to the arrangement of the elements of the tissue in which they lie. Thus in muscle, nerve, and tendon, the meshes are long and comparatively narrow, and run conformably with the fibres and fasciculi of these textures. In other parts, as in the lungs, in fat, and in secreting glands, the meshes are rounded or polygonal, with no one dimension greatly predominating. In the papillæ of the skin and mucous membranes, the vessels of the network are often drawn out into prominent simple or ramified loops.

The smallest arteries and veins pass by gradual transition into the capillary vessels, and their finest offsets approach very near to these in structure ; these may therefore be conveniently considered along with the capillary vessels.

Structure of the capillaries.—The wall of the capillaries proper is formed entirely of a simple epithelial layer, composed of flattened lanceolate cells joined edge to edge, and continuous with the corresponding layer which lines the arteries and veins. The outlines of the cells or their lines of junction one with another may be made apparent by nitrate of silver (fig. 188);

Fig. 188.

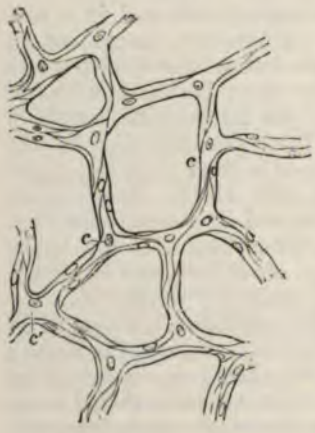


Fig. 188.—CAPILLARY VESSELS FROM THE BLADDER OF THE CAT, MAGNIFIED (after Chrzonszczewsky.)

The outlines of the cells are stained by nitrate of silver.

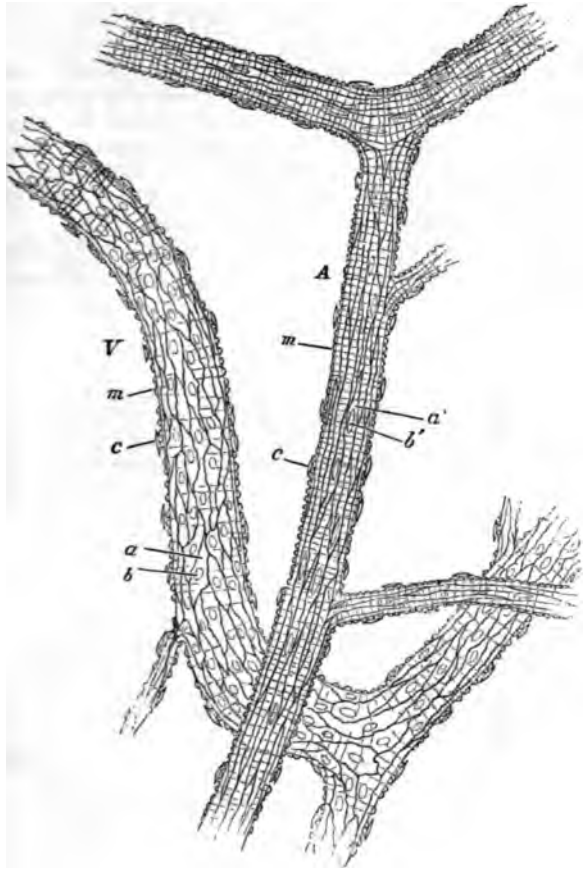
while the nuclei, which show a well-marked network of nucleoplasm, may be brought into view by logwood or carmine. Commonly there are not more than two or three such cells in the cross section of a capillary. At the points of junction of the capillaries the cells are usually broader and not spindle-shaped, but radiate, with three or four pointed branches fitting in between the cells of the three or four adjoining vessels which meet at the spot (fig. 188, *c*, *c*, *c'*).

In capillaries which have been submitted to the action of nitrate of silver, there is here and there to be seen between the cells of the capillary wall an increase in amount of the intercellular substance, appearing as an enlargement of the fine line of the silver deposit. To these gaps in the capillary wall, which however are closed by intercellular substance, J. Arnold has applied the term "stigmata ;" they are analogous to the "pseudo-stomata" found between the epithelium cells of a

membrane. It is probable that the white blood corpuscles, when migrating through the blood-vessels, pass between the epithelium-cells, especially in the neighbourhood of the stigmata.

The fixed cells of the surrounding areolar tissue are found connected intimately with the cells forming the capillary wall. This connection occurs almost everywhere, but it is more obvious in parts which are pervaded by a coarse network of retiform connective tissue, such as the substance of the

Fig. 189.



189.—A SMALL ARTERY A, AND VEIN V, FROM THE SUBCUTANEOUS CONNECTIVE SUE OF THE RAT. TREATED WITH NITRATE OF SILVER. 175 DIAMETERS (E. A. S.).

epithelium-cells with *b*, *b'*, their nuclei; *m*, *m*, transverse markings due to ed substance between the muscular fibre-cells; *c*, *c*, nuclei of connective tissue ss attached to exterior of vessel.

tic glands, the solitary and agminated intestinal glands and adjacent membrane, where the small vessels and capillaries may even obtain a ous covering from the reticulating processes of the cells. This coating has med by His, *adventitia capillaris*.

rowths from the capillary wall have been described by Stricker as occurring y in the progress of development, in the manner to be afterwards detailed, in the fully developed capillaries of the frog; and contraction both of

the whole capillary wall and also of the individual cells of young capillary ve has also been described (Stricker, Tarchanoff), but it is not known whethe walls of the capillaries of the adult mammal possess any appreciable contract

Structure of the small arteries and veins.—In vessels a l larger than the capillaries, there is added outside the epithelial l (fig. 189, *a*, *a'*), a layer of plain muscular tissue, in form of the t long contractile fibre-cells, which are directed across the length of vessel (fig. 189, *m*, *m*). The elongated nuclei of these cells ma brought into view by means of acetic acid or by staining fluids. layer corresponds with the middle coat of the larger vessels. the smallest vessels in which it appears the muscular cells are few apart, and a single long cell may turn spirally round the tube (Lis in larger vessels, especially those of the arterial system, the musc cells are more closely arranged. Outside the muscular coat is areolar or connective tissue coat, containing fibres and connec tissue corpuscles, with longitudinally placed nuclei.

In vessels of $\frac{1}{60}$ of an inch in diameter, or even less, the elastic la of the inner coat may be discovered (fig. 190, A, δ), in the form gene

Fig. 190.

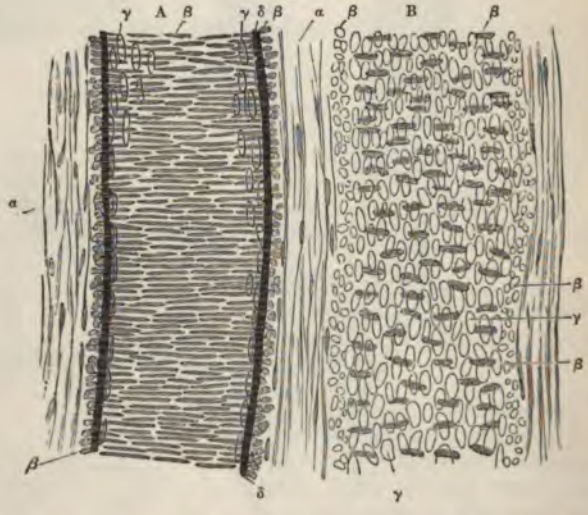


Fig. 190.—A SMALL ARTERY A, WITH A CORRESPONDING VEIN B, TREATED WITH ACID, AND MAGNIFIED 350 DIAMETERS (after Kölliker).

α, external coat with elongated nuclei; β, nuclei of the transverse muscular tissue middle coat (when seen endwise, as at the sides of the vessel, their outline is cir γ, nuclei of the epithelium-cells; δ, elastic layers of the inner coat.

of homogeneous or fenestrated membrane, more rarely of longitu reticulating elastic fibres. The small veins differ from arteries of c ponding size, chiefly in the inferior development of their muscular ti the lining cells of the arteries also are very much longer and nar than those of the veins. These differences, as well as the compa

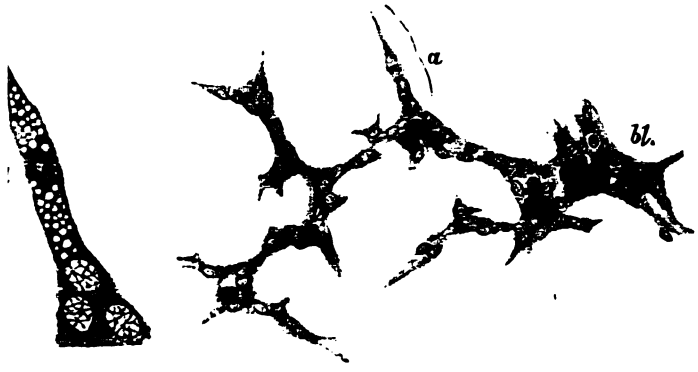
f corresponding vessels, are well shown in the accompanying
(189 and 190).

nly open communication between the arteries and the veins, is by means of
y vessels as above described, unless in the maternal part of the placenta and
nterior of erectile organs, in which small arteries may open directly into wide
cavities without the intervention of capillaries. Moreover, in the spleen the
capillaries do not at once pass into the commencements of the veins, but open
e interstices of the organ, from which the minute veins collect the blood.
said that in certain parts small arteries may pass into small veins without
ervention of true capillaries (Sucquet, Hoyer).
rial glands.—At the upper end of the common carotid (*carotid gland*) and
t of the apex of the coccyx (*coccygeal gland*, Luschka), are found small
oking bodies of a somewhat glandular appearance, but composed almost
r of a plexus of minute arteries, which are derived in the one case directly
ne carotid, in the other from the middle sacral. The plexiform vessels are
d by one or more layers of granular polygonal cells, apparently like those
n the interstitial tissue of some other organs (testis, ovary, thyroid, supra-
odies), and probably modifications of the more widely distributed plasma-
the connective tissue. The whole is invested by connective tissue, which
netrates between the vessels of the so-called gland, and itself contains
ne granular cells. The true nature and function of these peculiar struc-
entirely unknown.

DEVELOPMENT OF BLOOD-VESSELS.

first vessels which appear in the ovum are formed in the meso-
and the process subsequently goes on in the same layer and in its
tives in all parts of the animal body. New vessels, also, are formed
healing of wounds, in the restoration of lost parts, and in the

Fig. 191.



191.—PART OF THE NETWORK OF DEVELOPING BLOOD-VESSELS IN THE VASCULAR AREA OF THE GUINEA-PIG. (E. A. S.)

lood-corpuscles becoming free in an enlarged and hollowed out part of the net-
The smaller figure on the left represents *a* of the larger figure, more highly
ed; *d*, a nucleus undergoing division.

ction of adventitious growths. The process is in every case
ially the same.
first vessels of the embryo, both of the chick and mammal, are
l in the vascular area, and originate from some of the cells of the

mesoderm in that situation (fig. 191). Vacuoles are formed within the cells, and as they increase in size they run together, and a cavity filled with fluid is in this way produced in the interior of the cell, the nucleus of which has meanwhile become multiplied, while blood-corpuscles are formed within the cavity in the manner already described in connection with the blood (p. 34). The cells, whilst these changes are going on, increase largely in size, especially in the chick, where they form vesicles (fig. 192), visible to the naked eye as minute reddish specks, which have been known

Fig. 192.

Fig. 192.—CELLS FROM MIDDLE LAYER OF CHICK'S BLASTODERM UNDERGOING DEVELOPMENT INTO BLOOD-VESSELS. MAGNIFIED (from Klein).

a, cavity of cell; *b*, wall of cell; *f*, *f*, cells not yet hollowed out; *d*, blood-corpuscles.

since the time of Pander as "blood-islands." The cells are united to one another by their processes, and after a time the cavities become extended into the cell-processes, so that a network of vessels is by this means produced.

The wall of these primary vessels is therefore composed at first merely of the protoplasm of the original embryonic cells with a few nuclei, derived by division from the original nuclei of those cells, imbedded in it here and there. Subsequently the protoplasm becomes differentiated around the nuclei into the flattened cells which compose the wall of the capillaries, and which form the lining membrane of the arteries and veins. The remaining coats of the larger vessels are developed later, from other cells which apply themselves to the exterior of the previously simple tubes and produce the plain muscular and other tissues of which those coats consist.

Within the body of the embryo, vessels are formed in like manner from cells belonging to the connective tissue. One of the most favourable objects for the study of the development of the blood-vessels and their contained blood-corpuscles is afforded by the subcutaneous tissue of the new-born rat, especially those parts in which fat is being deposited.

Here we may observe that many of the connective tissue corpuscles are much vacuolated, and that the protoplasm of some of them presents a decided reddish tinge (fig. 193, *h*). In others the red matter has become condensed in the form of globules within the cells (*h'*, *h''*, &c.), varying in size from minute specks to spheroids of the diameter of a blood-corpuscle, or more. At some parts the tissue is completely studded with these cells, each containing a number of such spheroids, and forming, as it were, "nests" of blood-corpuscles or minute "blood-islands." After a time the cells become elongated and pointed at their ends, sending out processes also to unite with neighbouring cells. At the same time the vacuoles in their interior become enlarged, and coalesce to

n a cavity within the cell (fig. 194, *a*), in which the reddish globules, ch are now becoming disk-shaped (*b*), are found. Finally the cavity

Fig. 193.

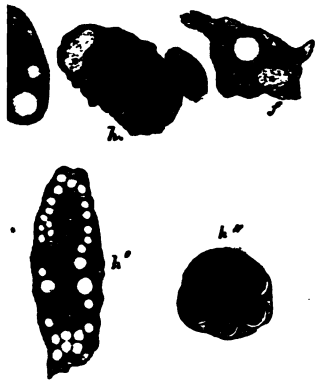
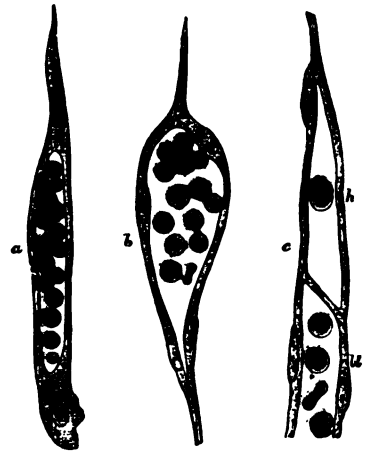


Fig. 194.



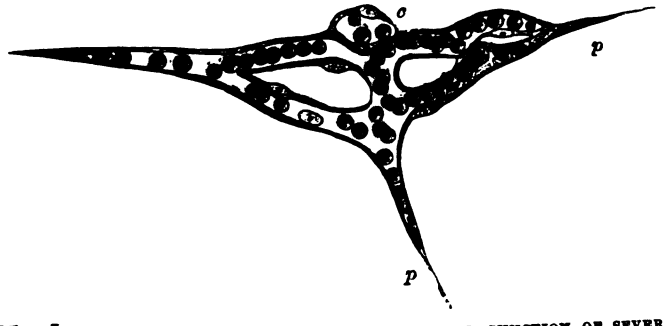
g. 193.—COMMENCING DEVELOPMENT OF CONNECTIVE TISSUE CELLS INTO BLOOD-VESSELS. FROM THE SUBCUTANEOUS TISSUE OF THE NEW-BORN RAT. (E. A. S.)

h, a cell containing hæmoglobin in a diffused form in the protoplasm; *h'*, one containing coloured globules of varying size, and vacuoles; *h''*, a cell filled with coloured globules of nearly uniform size; *f*, *f'*, developing fat cells.

g. 194.—FURTHER DEVELOPMENT OF CONNECTIVE TISSUE CELLS INTO CAPILLARY BLOOD-VESSELS. (E. A. S.).

a, an elongated cell with a cavity in its protoplasm occupied by fluid and by blood-corpuscles which are still globular; *b*, a hollow cell the nucleus of which has multiplied. The new nuclei are arranged around the wall of the cavity, the corpuscles in which have now become discoid; *c*, shows the mode of union of a "hæmapoietic" cell, which in this instance contains only one corpuscle, with the prolongation (*bl*) of a previously existing vessel. *a*, and *c*, from the new-born rat; *b*, from the fœtal sheep.

Fig. 195.



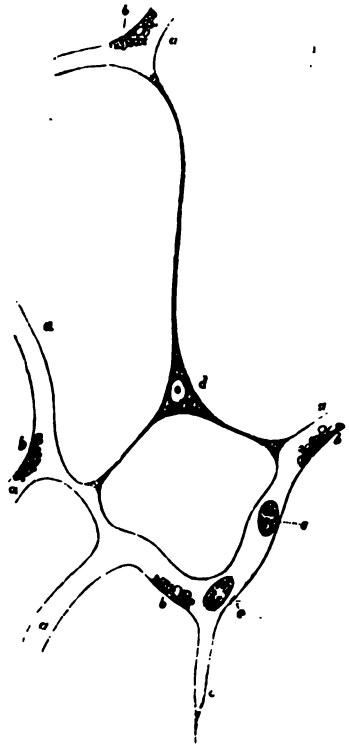
. 195.—ISOLATED CAPILLARY NETWORK FORMED BY THE JUNCTION OF SEVERAL HOLLOWED-OUT CELLS, AND CONTAINING COLOURED BLOOD-CORPUSCLES IN A CLEAR FLUID.

, a hollow cell the cavity of which does not yet communicate with the network; *p*, *p*, ated cell-processes, extending in different directions for union with neighbouring illaries.

extends through the cell processes into those of neighbouring cells [illegible] into those sent out from pre-existing capillaries (fig. 194, *bl*), but a [illegible] or less extensive capillary network is often formed long before the [illegible] nection with the rest of the vascular system is established (fig. 1[illegible] Young capillaries do not exhibit the well-known lines when treated [illegible] nitrate of silver, for the differentiation of the hollowed cells and [illegible] processes into flattened cellular elements is usually a subsequent pro[illegible]

The mode of extension of the vascular system in growing parts of [illegible] animals, as well as in morbid new formations, is quite similar to [illegible] here described, except that blood-corpuscles are not developed wi[illegible] the cells which are forming the blood-vessels.

Fig. 196.



The process of development of [illegible] lary vessels has long been studied [illegible] the tadpole's tail, and is represented [illegible] the adjoining figure (fig. 196) by Köll[illegible] in which the processes of a stellate [illegible] are seen to meet and join with similar [illegible] pointed processes which shoot out fr[illegible] the sides of neighbouring capillary ve[illegible] and in this manner the new vessels [illegible] adopted into the existing system. [illegible] junctions of the cells with each other [illegible] with capillary vessels are, at first, [illegible] great tenuity, and contrast strongly w[illegible] the central and wider parts of the cells.

Fig. 196.—CAPILLARY BLOOD-VESSELS IN [illegible] TAIL OF A TADPOLE, MAGNIFIED [illegible] DIAMETERS (Kölliker).

a, capillaries permeable to blood; *b*, accumulations of granules concealing the walls of the vascular wall; *c*, hollow prolongation of a capillary, ending in a point; *d*, a branched cell, containing a nucleus and granules, and communicating by these branches with prolongations of capillaries already formed; *e*, blood-corpuscles.

they appear then to be solid, but they afterwards become pervious and gradually widen, blood begins to pass through them, and the capillary network acquires a tolerably uniform calibre. The original vascular network may become closer by the formation of new vessels in its interstices. This is effected by similarly metamorphosed cells, arising in the areolæ and joining at various points with the surrounding vessels, and also simply by pointed offshoots from the existing capillaries stretching across the intervals and meeting from opposite sides, so as when enlarged to form new connecting arches.

The blood-vessels may be said to increase in size and capacity in proportion to the demands made on their service. Thus, as the uterus enlarges in pregnancy, its vessels become enlarged, and when the main artery of a limb is tied, or otherwise permanently obstructed, collateral branches, originally small and insignificant, augment greatly in size, to afford passage to the increased share of blood which they are required to transmit, and by this adaptation of them to the ex-

[illegible]cy, the circulation is restored. In such cases, an increase takes place in length, [illegible]well as in diameter, and accordingly the vessels very commonly become tortuous.

Recent Literature:—On the structure of blood-vessels in general:—*Eberth* in [illegible]cker's Handbook, 1871 (contains also literature up to that time); *Ranvier* in Traité [illegible]hnique, 1876.

On the structure of arteries:—*v. Ebner* in Med. Centralbl., 1869 (aorta); *Bresgen* in [illegible]rch. Arch., LXV. 1875; *Bardeleben* in Jena Sitzungsb., 1878; *Key-Aberg* (aorta) in [illegible]olog. Untera., herausg. von G. Retzius, 1881.

On the structure of veins:—*Bardeleben* in Jena Sitzungsb., 1877 and 1880.

On the structure of capillaries:—*Auerbach; Eberth; Aeby* in Med. Centralbl., 1865; [illegible]*rzonszczewsky*, Virch. Arch., XXXV. 1865; *Tarchanoff* in Pfluger's Arch., IX. 1874; [illegible]*icter* in Wiener Sitzungsb., 1876, and Med. Jahrb., 1878 (contractility).

On the development of blood-vessels:—*His*, Entwickl. d. Hühnchens, 1868; *Klein*, [illegible] Wiener Sitzungsb., LXIII. 1871; *Rouget* in Arch. de Physiol., 1872; *F. M. Balfour* [illegible] Quart. Jour. of Micr. Sci., 1872; *Schäfer* in Proc. Roy. Soc., 1873; *Ranvier* in Arch. [illegible] Physiol., 1873; *Schmidt* in Monthly Micr. Jour., 1875; *Leboucq* in Bull. d. l. Soc. de [illegible]d. de Gand, 1875, and Recherches, &c., 1876; *Kölliker*, "Entwickelungsgesch.," 1879.

LYMPHATIC SYSTEM.

Under this head we include not only the vessels specially called lymphatics or absorbents, together with the glands belonging to them, but also those named lacteal or chyliferous, which form part of the same system, and differ in no respect from the lymphatics, save that they not only carry lymph like those vessels, but are also employed to take up the chyle from the intestines during the process of digestion and convey it into the blood. An introductory outline of the lymphatic system has already been given at page 33.

A system of lymphatic vessels is superadded to the sanguiferous in all classes of vertebrated animals, but this is not the case in the invertebrata; in many of these, the sanguiferous vessels convey a colourless or nearly colourless blood, but no additional class of vessels is provided for conveying lymph or chyle.

Distribution.—In man and those animals in which they are present, the lymphatic vessels are found in nearly all the textures and organs which receive blood; the exceptions are few, and with the progress of discovery may yet possibly disappear. It is, however, with the connective tissue of the several textures and organs that the lymphatics are most intimately associated; indeed, as we shall immediately have occasion to notice, these vessels may be said to take origin in spaces in that tissue. The larger lymphatic trunks usually accompany the deeply-seated blood-vessels; they convey the lymph from the plexuses or sinuses of origin towards the thoracic duct. The principal lymphatic vessels of a part exceed the veins in number but fall short of them in size; they also anastomose or intercommunicate with each other much more frequently than the veins alongside of which they run.

It not unfrequently happens that a lymphatic vessel or a close interlacement of lymphatic vessels, may ensheath an artery or vein either partially or wholly. In this case the lymphatic is termed "perivascular."

Origin.—Two modes of origin of lymphatic vessels are described, viz., the *plexiform* and the *lacunar* or *interstitial*, but no sharp line of distinction can be drawn between them, the difference depending chiefly upon the nature of the tissue or organ to which the lymphatics are distributed. Thus in flat, membranous or expanded parts, the lymphatic vessels usually form a network which is situated either in a single plane, as in many parts of the serous membranes, or in two or more planes

united by intervening vessels, as in the skin and some mucous membranes. In the latter case the strata are generally composed of fine vessels, and form a closer network, the nearer they are to the surface of

Fig. 197.

Fig. 197.—LYMPHATIC PLEXUS OF CENTRAL TENDON OF DIAPHRAGM OF RABBIT, PLEURAL SIDE (Klein). MAGNIFIED.

a, larger vessels with lanceolate cells and numerous valves; *b*, *c*, lymphatics of origin, with wavy-bordered cells. Here and there an isolated patch of similar cells.

the membrane in which they are distributed, but even the most superficial and finest network is composed of vessels which are larger than the sanguiferous capillaries.

ymphatics of origin are often very irregular in size and shape
, *b*, *c*). In them the lymph is collected, and it is conveyed away
tissues and organs by more regular vessels provided with valves
, *a*), which again combine to form larger lymphatic trunks.
and there vessels are seen joining the plexuses of origin which
the tissue by a blind and often irregular extremity. A long-
nd well-marked example of such a mode of commencement is to
l in the lacteals of the intestinal villi, which, although they form
s in the larger and broader villi, arise in others by a single vessel
ng with a blind or closed extremity at the free end of the villus,
it sinks down to join the general plexus of the intestinal membrane.
he other hand in the more solid organs the lymphatic vessels
the interstices of the organ, and in many cases lose in great
their character of distinct tubular canals, and appear simply
like spaces; which are, however, always bounded by an epithelial
ke that which lines the lymphatic vessels elsewhere.
lacunar mode of origin of lymphatics was first described in the
y Ludwig and Tomsa, and it is now known to be characteristic of
ndular organs. Occupying everywhere the interstices of the
ting connective tissue, the lymph bathes the exterior of the
or alveoli of the gland, in many parts even separating them from
illary blood-vessels, so that the exchanges of material between the
of the blood and the secreting cells of the gland must be carried
ugh the intermedium of the lymph in these spaces. A network
hatic spaces is also met with between the anastomosing muscular
f the heart.
may be regarded as a third mode of origin of lymphatics is to
l in the open communications which subsist between the serous
and the lymphatic vessels in their walls. These orifices or
which will be described with the serous membranes, allow of
age of lymph from the serous cavities into the lymphatics, so
se cavities may, in a certain sense, be looked upon as large lymph

Owing to this communication fluid is not, under normal
tances, suffered to accumulate in them.

e of the lower animals the lacunar condition of lymphatics has been
wn. Rusconi found that the aorta and mesenteric arteries of amphibia
nd in large lymphatic spaces. Johannes Müller recognised the spaces
extensively separate the frog's skin from the subjacent muscles as
g to the lymphatic system, and Recklinghausen has shown that the sub-
s lymph-spaces of the frog's leg communicate with lymphatic vessels
nvelope the blood-vessels of the foot; also that milk injected into
ces finds its way into the blood. The lymphatic system, in being thus
ed by lacunæ or interstitial receptacles, so far agrees with the sangui-
stem of crustaceans and insects.

cture.—In structure the larger lymphatic vessels much resemble
s, only their coats are thinner, so thin and transparent indeed
e contained fluid can be readily seen through them. When
tics have passed out from the commencing plexuses and lacunæ,
found to have three coats. The internal coat is covered with
nelial lining, consisting of a single layer of flattened nucleated
hich have mostly an oblong or lanceolate figure, with an indented
tly serrated border, by which the adjacent cells fit to each other

(fig. 197, *a*). Outside the epithelial layer the inner coat is formed of a layer or layers of longitudinal elastic fibres. The middle coat consists of plain muscular tissue disposed circularly, mixed with finely reticulating elastic fibres taking the same direction. Over the dilatations which occur in the vessels beyond each of the valves, the circular disposition of the muscular fibres gives place to a more irregular disposition, taking the form of an intricate interlacement of fibres. The external coat is composed mainly of white connective tissue with a sparing intermixture of longitudinal elastic fibres, and some longitudinal and oblique bundles of plain muscular tissue. In the thoracic duct there is a subepithelial layer (as in the arteries); and in the middle coat there is a longitudinal layer of white connective tissue with elastic fibres, immediately within the muscular layer. The muscular fibres of the middle coat, although for the most part transverse in direction, are nevertheless many of them oblique or even longitudinal.

The larger lymphatics have bloodvessels ramifying in their outer coat.

The commencing lymphatics or lymphatic capillaries, whether in plexuses or single (as in the villi), have a much simpler structure, their wall being entirely formed of a layer of flattened epithelial cells either similar in form to those lining the larger vessels or (more frequently) presenting a characteristic waved border like the epidermic cells of grasses and some other plants (fig. 198).

Fig. 198.

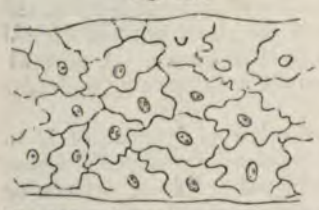


Fig. 198.—EPITHELIUM OF COMMENCING LYMPHATIC (Auerbach). 240 DIAMETERS.

Gaskell describes an attachment of elastic fibres to the walls of the smaller lymphatics in some parts, and infers that the patency of the lumen of these vessels may by this means be restored after it has been temporarily obliterated by pressure.

Valves.—The lymphatic and lacteal vessels are furnished with valves serving the same office as those of the veins, and for the most part constructed after the same fashion. They generally consist of two semilunar folds arranged in the same way as in the valves of veins already described, but deviations from the usual structure here and there occur. A difference is found in the epithelium upon the two surfaces of the valves similar to that which has been noticed in the valves of the veins.

Valves are not present in all lymphatics, but where they exist they follow one another at much shorter intervals than those of the veins, and give to the lymphatics, when much distended, a beaded or jointed appearance. Valves are placed at the entrance of the lymphatic trunks into the great veins of the neck. They are generally wanting in the reticularly arranged vessels which compose the plexuses of origin already spoken of; so that fluid injected into one of these vessels runs in all directions, so as to fill a greater or a less extent of the plexus, and passes along the separate vessels which issue from it.

The lymphatics of fishes and amphibia are, generally speaking, destitute of valves, and may therefore be injected from the trunks; in the turtle a few valves are seen on the larger lacteals which pass along the mesentery, but none on those in the coats of the intestine; and valves are

ch less numerous in the lymphatics and lacteals of birds than in e of mammiferous animals.

Relation of the lymphatics of origin to the cells and cell-spaces the connective tissue.—It has been already stated (p. 58) that cells of the connective tissue lie in spaces in the ground-substance h they more or less completely fill. These cells and cell-spaces in many parts an intercommunicating network of varying fineness ding throughout the substance of the tissue (fig. 199, *d*, *d*,

Fig. 199.

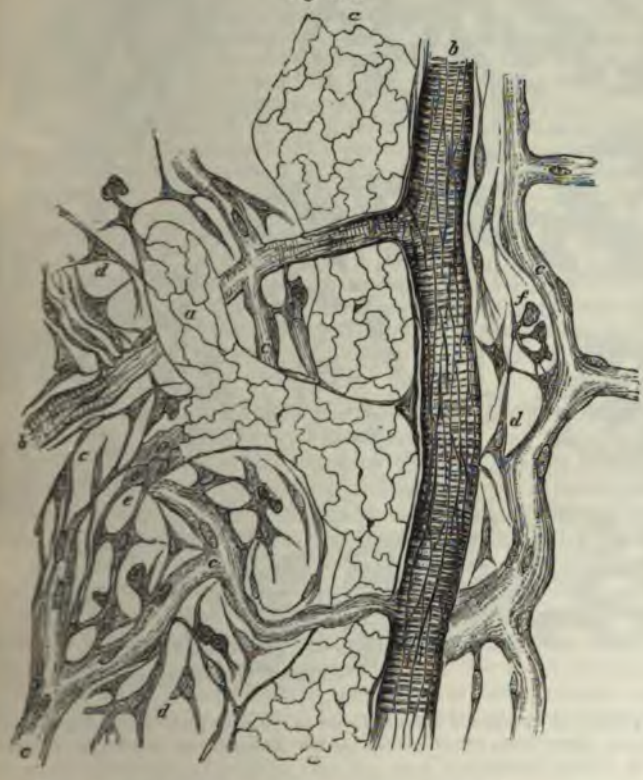


Fig. 199.—Nitrate of silver preparation from rabbit's omentum (Klein). Magnified.

lymphatic vessel ; *b*, artery ; *c*, capillaries ; *d*, branched cells of the tissue which en to be connected both with the capillary walls, and, as at *e*, with the lymphatic.

200, *c*, *c*), whilst in other parts the cells acquire a broad flattened , and joining edge to edge with other similar cells may in this way an epithelioid patch in the ground substance. Not unfrequently cells in such a patch take on the wavy border described above met with in the lymphatics of origin (see the isolated patches fig. 197). Further, the flattened cells which form the walls of lymphatics are connected here and there both with the more ified cells of the tissue (fig. 199, *e*) and with those which form

the epithelioid patches, and in silvered preparations they appear to be continuous with one another. The epithelioid patches look in fact like a part of the lymphatic vessels, and are commonly regarded as such: it must be understood, however, that the spaces here spoken of, whether containing single cells or groups, are not true *vessels*, but merely vacu-

Fig. 200.

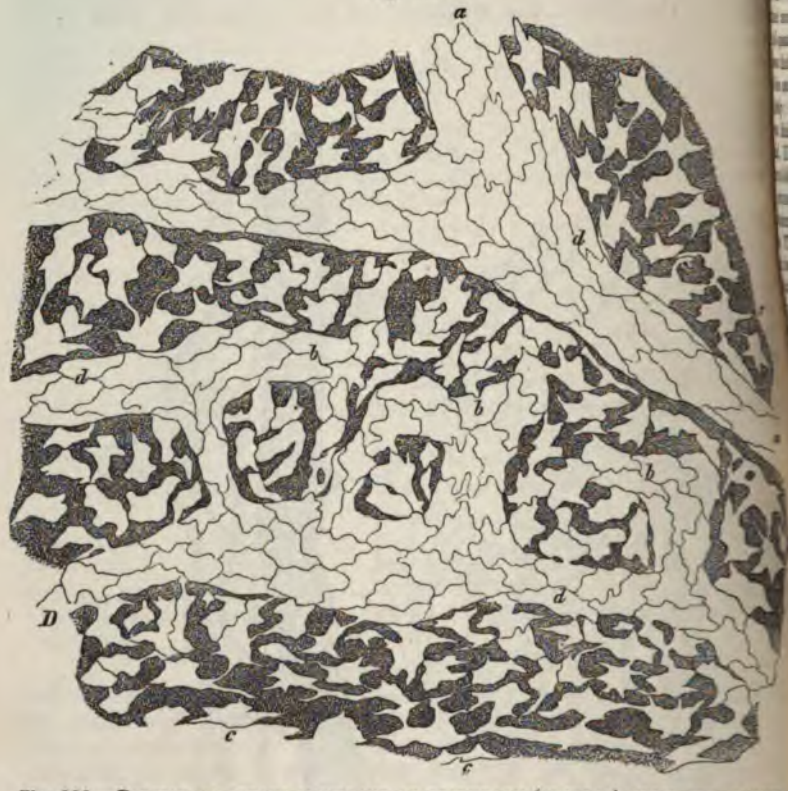


Fig. 200.—PORTION OF SEROUS MEMBRANE OF DIAPHRAGM (PLEURAL) FROM THE RABBIT, TREATED WITH NITRATE OF SILVER AFTER REMOVAL OF SUPERFICIAL EPITHELIAL LAYER (Recklinghausen).

c, *c*, cell-spaces of tissue; *d*, *d*, commencing lymphatic vessels connected at *b*, *b*, with the cell-spaces.

ties in the ground-substance of the tissue containing flattened cells, which do not form a continuous vascular wall. And although the spaces present a very close relation to the lymphatic vessels, they can hardly be considered as actually opening into them by patent orifices, for the lymphatics proper have a complete wall of flattened cells united by a small amount of intercellular substance: at the same time this thin film can offer but a very slight resistance to the passage of fluid from the tissue into the vessel, or even to the passage of leucocytes or migrating cells, which, as is well known, penetrate the at least equally closed wall of the blood-vessels.

Lymphatic hearts.—J. Müller and Panizza, nearly about the same time, but independently of each other, discovered that the lymphatic system of reptiles is furnished, at its principal terminations in the venous system, with pulsating muscular sacs, which serve to discharge the lymph into the veins. These organs, which are named lymph-hearts, have now been found in all the different orders of reptiles. In frogs and toads two pairs have been discovered, a posterior pair situated in the sciatic region, which pour their lymph into a branch of the sciatic or of some other neighbouring vein, and an anterior more deeply-seated pair, placed over the transverse process of the third vertebra, and opening into a branch of the jugular vein. The parietes of these sacs are thin and transparent, but contain muscular tissue, which here and there appears obscurely striated, decussating in different layers, as in the blood-heart. In their pulsations they are quite independent of the latter organ, and are not even synchronous with each other. In salamanders, lizards, serpents, tortoises, and turtles, only a posterior pair have been discovered, which, however, agree in all essential points with those of the frog. In the goose, and in other species of birds belonging to different orders, Panizza discovered a pair of lymph-sacs opening into the sacral veins, and Stannius has since found that these sacs have striated muscular fibre in their parietes. Nerve-fibres, both dark-bordered and pale, have been observed in the lymph-hearts of the frog, and also nerve-cells in those of the common tortoise (Waldeyer).*

Development of lymphatic vessels.—The development of lymphatic capillaries has been studied by Klein in the serous membranes. He finds that the process is similar to that of the development of blood-vessels. A vacuole is formed within one of the cells of the connective tissue, and becomes gradually larger, so as ultimately to produce a cavity filled with fluid, with the protoplasm of the cell thinned out to form the wall of the vesicle thus produced. From this protoplasmic wall portions bud inwards into the cavity, eventually becoming detached as lymph-corpuscles. Meanwhile the nucleus of the cell has become multiplied, and the resulting nuclei are regularly arranged in the protoplasmic wall, which now exhibits, on treatment with nitrate of silver, the well-known wavy epithelial marking characteristic of the lymphatic capillaries. To form vessels, the vesicles become connected with one another by means of processes into which their cavities extend.

The cells lining these lymphatic vesicles, which are common in the mesogastrium of the frog and toad in the winter season bear, in the female of those animals, cilia directed inwards towards the cavity of the vesicles. As the development into vessels proceeds, the cilia disappear (Klein). Remak, who first noticed these ciliated vesicles, took them for cysts in the membrane.

Kölliker has observed the formation of lymphatics from ramified cells in the tails of young salamander-larvæ. He states that the process takes place nearly in the same manner as in the case of sanguiferous capillaries; the only notable difference being, that whilst the growing lymphatics join ramified cells, and thus extend themselves, their branches very rarely anastomose or become connected by communicating arches.

LYMPHATIC GLANDS.

Lymphatic glands, named also *conglobate glands*, and by modern French writers *lymphatic ganglions*, are small solid bodies placed in the

* Müller's description is to be found in the Philosophical Transactions for 1833; Panizza's in a special memoir on the Lymphatic System of Reptiles, published in the same year. For a more complete account of the lymphatic hearts the reader is referred to the "Leçons d'Anatomie Générale," delivered by Prof. Ranvier in the Collège de France in 1877–78, and published in 1880. A paper on the same subject by Mr. J. Priestley in the Journal of Physiology, Vol. I. 1878, may also be consulted.

...rse of the lymphatics and lacteals, through which the contents of these ...sels have to pass in their progress towards the thoracic or the right ...phatic duct. These bodies are collected in numbers alongside of ... great vessels of the neck, and also in the thorax and abdomen, espe-...lly in the mesentery and alongside of the aorta, vena cava inferior, and ... vessels. A few, usually of small size, are found on the external ...ts of the head, and considerable groups are situated in the axilla and ...in. Some three or four lie on the popliteal vessels, and usually one ...placed a little below the knee, but none farther down. In the arm ... are found as low as the elbow joint.

The lymph of some lymphatic vessels has to traverse two, three, or ...n more lymphatic glands before reaching the thoracic duct, whilst, on ... other hand, there are lymphatics which enter the thoracic duct ...hout having traversed any gland in their way.

The size of lymphatic glands is very various, some being not much ...er than a hempseed, and others as large as an almond or a kidney

Fig. 201.

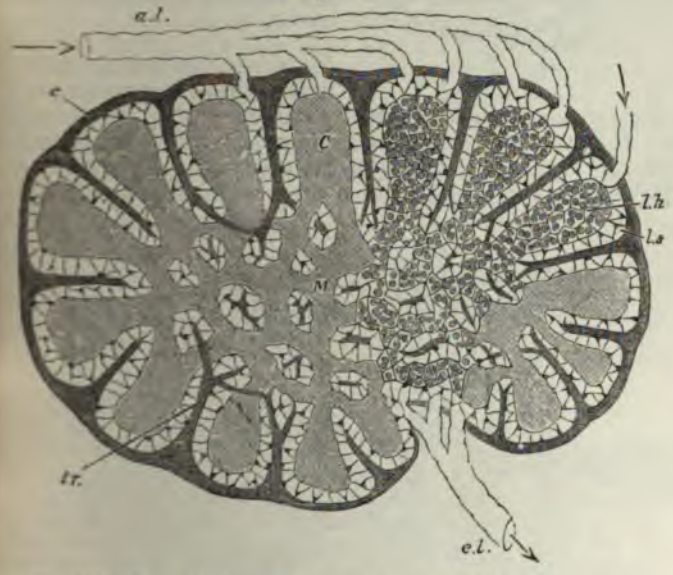


Fig. 201.—Diagrammatic section of lymphatic gland (Sharpey).

...a. *l*, afferent; *e. l*, efferent lymphatics. C, cortical substance. M, reticulating cords ... medullary substance. *l. s*, lymph-sinus; *c*, fibrous coat sending trabeculæ, *tr*, into ... substance of the gland.

...n, or even larger than this. In shape, too, they present differences, ...t most of them are round or oval.

The lymphatics or lacteals which enter a gland are named inferent or ...erent vessels (*vasa inferentia* seu *afferentia*), and those which issue ...m it efferent vessels (*vasa efferentia*). The afferent vessels (fig. 201, ...), on approaching a gland, divide into many small branches, which ...er the gland; the efferent vessels commonly leave the gland in the form ...small branches, and at a little distance beyond it, or sometimes even

before issuing from it, unite into one or more trunks (*e. l*), usually in size but fewer in number than those of the afferent vessels.

A lymphatic gland is covered externally with a coat (figs. 201, composed of connective tissue, mixed, in certain animals, with cular fibre-cells. This coat or capsule dips into the interior gland at the place where the larger blood-vessels and the e lymphatics pass into and out of the organ ; and this part of the which often presents a depression or fissure, is named the *hilu* 202, *a*). The proper substance of the gland consists of two pa *cortical* (fig. 201, *C*), and this the *medullary* (*M*). The occupies all the superficial p the gland, except the hilus,

Fig. 202.

Fig. 202.—SECTION OF A MESENTER FROM THE OX, SLIGHTLY M (Kölliker).

a, hilus ; *b*, medullary substance ; tical substance with indistinct alv capsule.

the larger glands may attain a ness of one or two millimeters. medullary portion occupies the centre and extends to the surface hilus. It is most developed in the inwardly-seated glands, such lumbar and mesenteric, whilst in the subcutaneous glands it is encroached upon by the connective tissue which enters with the

Fig. 203.

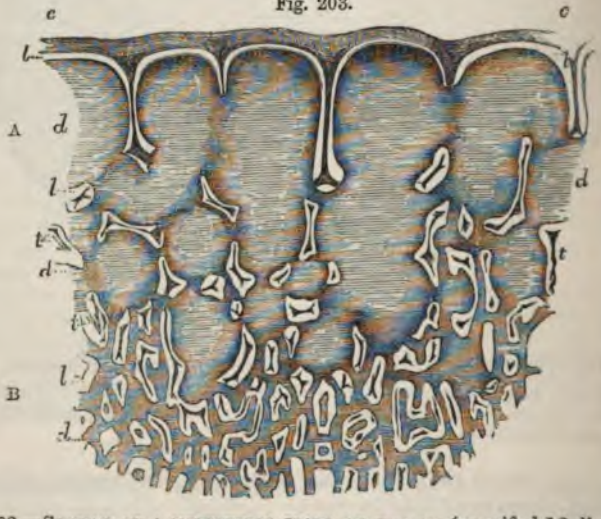


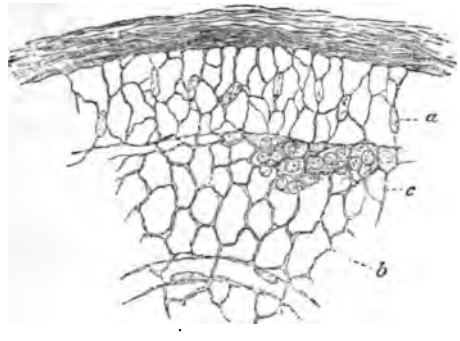
Fig. 203.—SECTION OF A MESENTERIC GLAND OF THE OX (magnified 12 diam After His.

The section includes a portion of the cortical part, A, in its whole depth, and portion of the adjoining medullary part, B ; *c*, *c*, outer coat or capsule sending into the cortical part, eventually forming the trabeculæ, *t*, *t*, which are seen mostly c *d*, *d*, the glandular substance forming nodules in the cortical part, A, and ret cords in the medullary part, B ; *l*, *l*, lymph-sinus or lymph-channel, left white.

d-vessels at the hilus, and surrounds them, together with the lymph-
ds, in the centre of the gland, so that in these the medullary part is
ced to a layer of no great thickness bounding inwardly the cortical

hroughout both its cortical and medullary part the gland is pervaded
trabecular frame-work which incloses and supports the proper glan-
r substance. The trabeculæ pass inwards from the capsule (fig. 203).
consist, in the ox and most animals, chiefly of plain muscular tissue;
an, of connective tissue, sparingly intermixed with muscular fibre-
. In the cortical part they are mostly lamellar in form, and divide
pace into small compartments, *alveoli*, from $\frac{1}{60}$ to $\frac{1}{24}$ of an inch wide,
h communicate laterally with each other through openings in the
rfect partitions between them (fig. 203, A). On reaching the
ullary part the trabeculæ take the form of flattened bands or cords,
by their conjunction and reticulation form a freely intercommuni-
ng meshwork throughout the interior. (In the figure they are repre-
ed mostly as cut across.) In these alveoles and meshes is included
proper *glandular substance*, which appears as a tolerably firm pulp
arenchyma, agreeing in nature with lymphoid tissue. Within the
oli of the cortical part this forms rounded nodules (fig. 203, A, *d*);
he trabecular meshes of the medullary part it takes the shape of
ded cords (*lymphoid cords*) joining in a corresponding network
. 203, B, *d*); and, as the containing meshes inter-communicate, so the
ained gland-pulp is continuous throughout. But both in the
ical alveoles and the medullary trabecular meshes, a narrow space,
white in the figs. (fig. 201, *l. s*; 203, *l*, *l*) is left all round the
nd-pulp, between it and the alveolar partitions and trabecular bands,
what would be left had the pulp shrunk away from the inside of a
uld in which it had been cast. This space is both a receptacle and
hannel of passage for the lymph that goes through the gland; it is
ned the *lymph-sinus*, or *lymph-channel*. It is traversed by reti-
m connective tissue (figs. 204, *a*; 205, *c*, *c*), in which the nuclei of

Fig. 204.



. 204.—THIN SECTION FROM HE CORTICAL PART OF A YMPHATIC GLAND, MAGNIFIED. His.)

a, *b*, network of fine trabeculæ ned by retiform or adenoid ue, from the meshes of which lymph-corpuscles have been hed out, except at *c*, where y are left.

ramified cells are stly apparent, and is d with fluid lymph, con-ing many lymph-cor-cles, which may be hed out from sections of gland, so as to show the sinus, while the firmer gland-pulp, which the ts surrounds, keeps its place. The proper glandular substance is pervaded and supported by small but fine retiform tissue, mostly -nucleated (figs. 204, *b*, 205, *a*), communicating with that of the rounding lymph-sinus, but marked off from it by somewhat closer

reticulation at their mutual boundary, not so close, however, as to prevent fluids, or even corpuscles, from passing from the one to the other. The gland-pulp is made up of densely packed lymphoid cells, occupying the interstices of its supporting retiform tissue, and is traversed by an abundant network of capillary blood-vessels (*d*, *d*), which run through the proper glandular pulp, both cortical and medullary, but do not pass into the surrounding lymph-sinus. The lymphoid cells of the gland-pulp are similar in their general appearance to white blood- or lymph-corpuscles, except that their nucleus is relatively larger, and their protoplasm much smaller in amount.

Fig. 205.

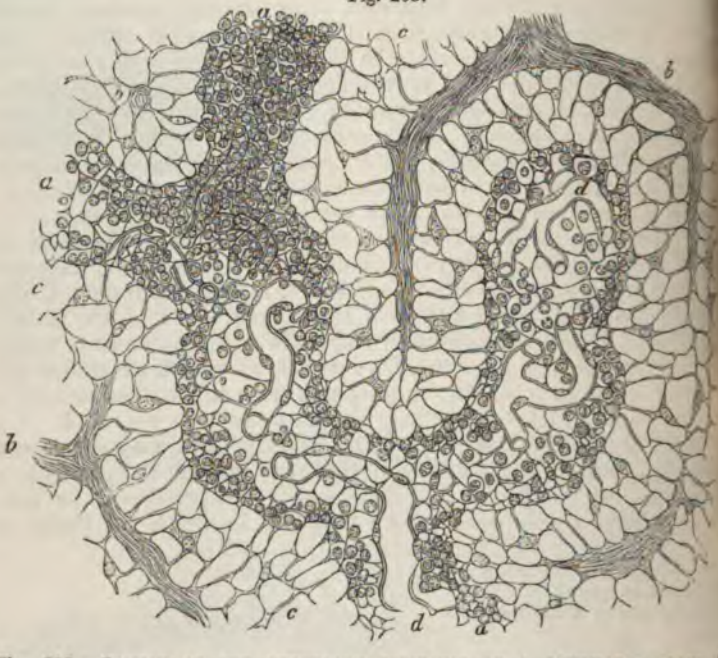


Fig. 205.—Section of the medullary substance of a lymphatic gland (ox). 300 diameters. (Recklinghausen.)

a, *a*, *a*, follicular or lymphoid cords; *c*, lymph-sinus; *b*, *b*, trabeculæ; *d*, *d*, blood-vessels.

The ramified cells of the retiform tissue of the lymph-sinus, which often contain a considerable number of pigment-granules, enclose fine anastomosing bundles of connective tissue fibrils which are continued from the trabeculæ and from the capsule across the lymph-channel (Bizzozero), and pervade the whole of the glandular pulp with a fine network. The trabeculæ themselves have a covering of flattened cells, which on the side turned towards the lymph-channel are provided with processes to anastomose with those of the retiform tissue. The inner surface of the capsule is also lined with flattened cells, which are continuous at the entrance and exit of the lymphatics with the epithelium of those vessels.

According to Bizzozero there is also a complete layer of flattened cells to the glandular pulp.

rteries enter and veins leave the gland at the hilus, surrounded, in
e glands, as already said, with a dense investment of connective tissue.
arterial branches go in part directly to the glandular substance, but
y run along the trabeculæ. The former end in the glandular
llary network above-mentioned, from which the veins begin, and
to the hilus alongside the arteries. The branches which run along
rabeculæ are partly conducted to the coat of the gland to be there
ributed; but most of their branches pass to the glandular substance,
connective tissue of the trabeculæ which ensheaths them passing
ually into the lymphoid tissue of the pulp, so that this at first
ears as a sheath to the arterial branch (as in the spleen). The
r soon however breaks up into capillaries which ramify in the
d-pulp, supported by its pervading retiform tissue, which forms an
itional adventitious coat around the minute vessels.

s to the lymphatics of the gland, the afferent vessels, after branching
upon and in the tissue of the capsule, send their branches through
open into the lymph-sinuses of the cortical alveoli, and the efferent
phatics begin by fine branches leading from the lymph-sinuses of the
llary part, and forming at the hilus a dense plexus of tortuous and
icose-looking vessels, from which branches proceed to join the larger
rent trunks. The lymph-sinus, therefore, forms a channel for the
ge of the lymph, interposed between the afferent and efferent
phatics, communicating with both, and maintaining the continuity
he lymph-stream. The afferent and efferent vessels, where they open
the lymph-sinus, lay aside all their coats, except the epithelial lining,
ich is continued over the trabeculæ and the interior of the capsule.

t is not unreasonable to presume that, in the proper glandular substance, there
continual production of lymph-corpuscles, which pass into the lymph-sinus,
that fresh corpuscles are thus added to the lymph as it traverses the gland.
is view is supported by the fact, that the corpuscles are found to be more
ndant in the lymph or chyle after it has passed through the glands.

Other organs composed of lymphoid tissue.—Bodies which are so far similar
structure to lymphatic glands that they are composed of a retiform tissue, the
rstices of which are closely packed with lymphoid cells, and are in intimate
ation with the lymphatic vessels of the part, occur in many places. Thus,
the serous membranes, rounded nodules are here and there met with, which,
Klein has shown, are developed either around or at one side of an en-
ged lymphatic (perilymphangial nodule, fig. 206, A), or in some cases even
hin the vessel (endolymphangial nodule, fig. 206, B). The retiform tissue
ich constitutes the framework of the nodule is connected with the flat cells
ning the wall of the lymphatic, and lymphoid cells accumulate in the
rstices of the retiform tissue.

he endolymphangial nodules, although small and simple in structure,
ely recall the structure of one of the cortical nodules of a lymphatic gland;
a path or channel for the passage of lymph is left between the central
mulation of lymphoid tissue and the wall of the vessel, this path being
ged across by branched cells of the retiform tissue; and along it the lymph
t pass very slowly, and come into intimate relation with the tissue of the
ule. In other cases the lymphoid tissue of the serous membranes is less cir-
scribed, occurring in the form of ill-defined patches or elongated tracts,
ch lie along the course of the small arteries and veins, receiving from the
r branches which form a capillary network within the tissue.

mucous membranes, especially that lining the alimentary canal, con-
nous lymphatic nodules are met with in various parts, and here they have
long known. They occur either singly, as in the so-called solitary glands

of the intestine, or collected into groups as in the agminated glands or patches of Peyer, or into thick masses as in the tonsils. In most of these cases the nodules are spherical or dome-shaped condensations of the lymphoid tissue which occurs largely in the substance of the mucous membrane, on the surface of which they may cause a distinct prominence; they are usually found to be in close relation with the lymphatics of the membrane, being either partially surrounded by a large sinus-like lymphatic, or encircled by a plexus of lymphatic vessels. In the mucous mem-

A Fig. 206 B

Fig. 206.—Developing lymphatic (lymphangial) nodules, from the omentum of a guinea-pig (Klein).

A, Perilymphatic nodule; *a*, lymphatic vessel; *c*, part of its epithelial wall, seen in optical section; *e*, lymph-corpuscles within the vessel; *b*, lymphoid tissue of the nodule; *d*, blood-capillaries. B, Endolymphatic nodule; *a*, vein; *b*, artery; *c*, capillaries; *d*, lymphatic vessel, in which this whole system of blood-vessels is inclosed; *e*, lymphoid tissue within the lymphatic vessel; *f*, wall of the lymphatic in optical section.

brane of the bronchial tubes nodules are met with which are quite similar to those of the serous membranes. In the spleen, tracts of lymphoid tissue, with lymphatics in connexion with them, ensheath the smaller arteries and are dilated at certain points into distinct nodules which have here long been known as the Malpighian corpuscles of the spleen. Lastly the thymus gland seems to be chiefly composed in the young subject of a collection of lymphoid tissue, although in the adult it is usually found to have become transformed into adipose tissue.

The further description of these lymphoid structures, will be deferred until the several organs where they occur are systematically treated of

SEROUS MEMBRANES.

The serous membranes are so named from the apparent nature of the fluid with which their surface is moistened. They lie in cavities of the body which have no obvious outlet, and the chief examples of them are, the peritoneum, the largest of all, lining the cavity of the abdomen; the two pleuræ and the pericardium in the chest; and the tunica vaginalis surrounding each of the testicles within the scrotum.

The arachnoid membrane, which is a delicate connective-tissue membrane surrounding the brain and spinal marrow in the bony cavities in which they are

ined, was formerly reckoned amongst the serous membranes; but neither in etails of its structure, in its general disposition, nor in its development does respond with the other serous membranes. It is, therefore, no longer classed them, but will be described with the other membranes investing the brain pinal cord.

rm and arrangement.—In all cases a serous membrane has the of a closed sac, one part of which is applied to the walls of the y which it lines, the *parietal* portion; whilst the other is reflected the surface of the organ or organs contained in the cavity, and is fore named the *reflected* or *visceral* portion of the membrane. e the viscera in such cavities are not contained within the sac of erous membrane, but are really placed behind or outside of it; ng to push inwards the part of the membrane which immediately s them, some organs receiving in this way a complete, and others a partial and sometimes very scanty investment.

passing from one part to another, the membrane frequently forms which in general receive the appellation of ligaments, as, for ple, the folds of peritoneum passing between the liver and the tes of the abdomen, but which are sometimes designated by special s, as in the instances of the mesentery, mesocolon, and omentum. ıe peritoneum in the female sex, is an exception to the rule that ıs membranes are perfectly closed sacs, inasmuch as it has two ings by which the Fallopian tubes communicate with its cavity.

serous membrane sometimes lines a fibrous membrane, as where the ıs layer of the pericardium adheres to its outer or fibrous part. ı a combination is often named a *fibro-serous* membrane.

he inner surface of a serous membrane is free, smooth, and polished; , as would occur with an empty bladder, the inner surface of one of the sac is applied to the corresponding surface of some other ; a small quantity of fluid, usually not more than merely moistens contiguous surfaces, being interposed. The parts situated in a ity lined by serous membrane, being themselves also covered by it, can glide easily against its parietes or upon each other, and their ion is rendered smoother by the lubricating fluid.

he outer surface most commonly adheres to the parts which it lines overs, the connection being effected by means of areolar tissue, ed therefore "subserous," which, when the membrane is detached, s to its outer and previously adherent surface a flocculent aspect. degree of firmness of the connection is very various: in some parts membrane can scarcely be separated; in others, its attachment is so ıs to permit easy displacement.

tructure and properties.—Serous membranes are thin and transpa-, so that the colour of subjacent parts shines through them. They are ably strong, with a moderate degree of extensibility and elasticity. y are lined on the inner surface by a simple epithelial layer of flat- d cells (fig. 207), each of which contains a round or oval nucleus one or two nucleoli, and sometimes an intranuclear network. The have, according to Klein, a comparatively coarse network of minute ls embedded in the otherwise clear cell-substance. The outlines of ells may readily be brought into view by treatment with nitrate of r. The lines of junction of the cells which are thus made evident, be straight and even, but are most commonly slightly jagged or

sinuous. Here and there between the cells apertures are to be
which are of two kinds. The smaller, which are also the
numerous, are occupied either by an accumulation of the intercel
substance or by processes which are sent up to the surface of the
brane from more deeply lying cells (*pseudostomata*, Klein and Bur
Sanderson): the larger ones, on the other hand, are true aper
(*stomata*), which are surrounded by a ring of small cubical cells
208, *s*, *s'*), and open into a subjacent lymphatic vessel, either dire
or by the medium of a short canal lined with similar cells. The

Fig. 207.

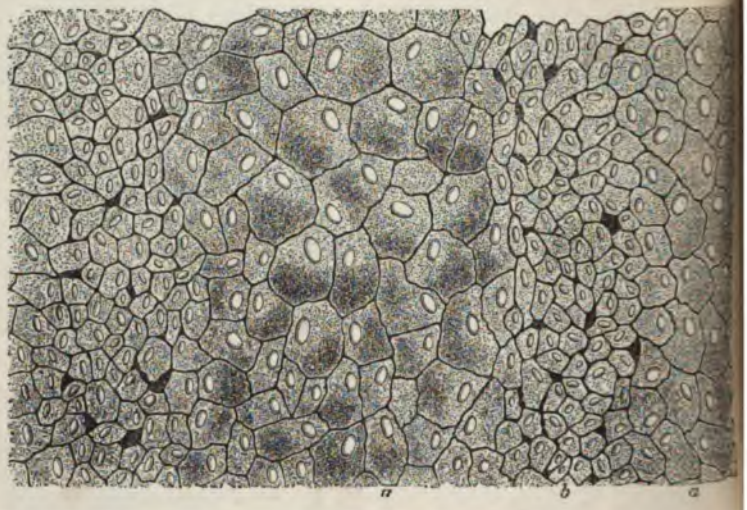


Fig. 207.—PORTION OF EPITHELIUM OF PERITONEUM FROM DIAPHRAGM OF RA
(Klein).

a, larger cells. *b*, smaller ones, with here and there a pseudostoma between.

cells of the serous membrane are not everywhere uniform in size (fig. 20
but patches are here and there met with in which they are smaller a
more granular in appearance and it is in these parts that the stom
and pseudo-stomata are more frequently seen. The epithelium-cells
the membrane often present a somewhat radiated aspect near
stomata, the silver lines converging towards the orifice. According
Klein, it is not unfrequent to find evidences of proliferation, especia
in the neighbourhood of the stomata and pseudostomata, cells being
with containing two or even many nuclei, and others which are be
budded off from the epithelium-cells of the membrane in the form
amœboid lymph-corpuscles.

The stomata were discovered in the peritoneal covering of the central ten
of the diaphragm by Recklinghausen, who found that milk-globules could
made to pass through them into the lymphatics. Similar apertures were fo
by Ludwig and Dybkowsky in the pleura of mammals, and by Schweigger-Se
and Dogiel in the septum between the peritoneal cavity of the frog and the g

[redacted]h-sac (cisterna magna) behind it. They have since been discovered on the [redacted]ntum by Klein, but have not hitherto been shown to exist in the pericardium [redacted] in the tunica vaginalis.

[redacted]he substance of the membrane underneath the epithelium is com[redacted]ed of a connective tissue ground-substance in which is a variable [redacted]ount of fibres, both white and elastic; the latter in many serous [redacted]mbranes, as remarked by Henle, are principally collected into a [redacted]icular layer near the surface. The bundles of white fibres are also [redacted]anged in a reticular manner, frequently uniting with one another,

Fig. 208.

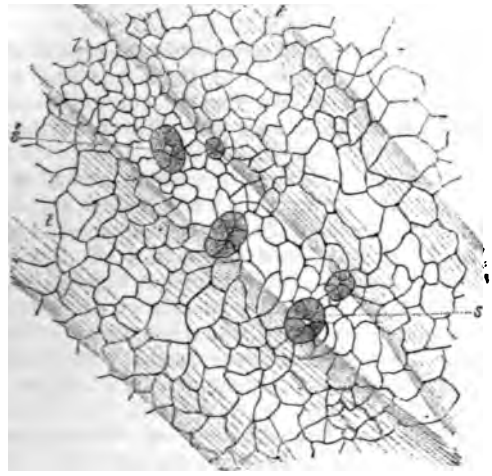


Fig. 208.—Small portion of peritoneal surface of diaphragm of rabbit (Klein). Magnified.

l, lymph-channel below the surface, lying between tendon bundles, *t*, *t*, and over which the surface-cells are seen to be relatively smaller, and to exhibit five stomata, *S*, *S*, leading into the lymphatic. The epithelium of the lymphatic channel is not represented.

and the meshes of the reticulation which they form are occupied by the ground-substance of the membrane, and bridged over by the epithelium-cells of the general surface. In some folds of the serous membranes and especially in the great omentum of many animals, including man, the meshes of the reticulation have become open in many parts owing to the absorption of the intervening ground-substance, so as to allow of a free communication between the two sides of the fold of membrane. In these places the epithelium-cells of the surface are applied to the anastomosing connective tissue bundles, and folded round them so as to bound the apertures between the two surfaces. Where the membrane is thicker, the ground-substance contains bloodvessels and lymphatics, with the lymphoid and adipose tissue which is often found in the serous membranes and especially in their folds; as well as connective tissue corpuscles with their corresponding cell-spaces (figs. 199, 200), which in the serous membranes are very often collected into epithelium-like patches. In parts of the membrane in which the cor-

puscles are more thinly scattered, they possess branching processes some of which intercommunicate with those of neighbouring cells others may pass up to the surface of the membrane as pseudostomata and others again, become connected to the walls of the lymphatics and blood-vessels.

In the human subject, the serous membranes appear to be bounded under the epithelium by a distinct basement membrane (Bizzozero).

The **blood-vessels** of the membrane end in a capillary network with comparatively wide meshes, which pervades the subserous tissue and the tissue of the serous membrane. The vessels are much more numerous in the nodules and tracts of lymphoid tissue (see below) as well as in the adipose tissue, which is found largely developed in the serous membranes of fat animals.

The **lymphatics** of the serous membranes are exceedingly abundant. Their relation both to the cell-spaces of the tissue and to the surface of the membrane, as well as their general arrangement, has been already noticed. They are sometimes met with ensheathing the blood-vessels.

Lymphoid tissue.—Nodules of this tissue occur, as before mentioned (p. 213), in the substance of the serous membranes. More generally the lymphoid tissue of the serous membranes takes the shape of elongated tracts which follow the course of the small arteries and veins, receiving from the latter branches which divide to form a capillary network. Lymphatic vessels run in these tracts alongside the blood-vessels, and often partially enclose them. These lymphoid nodules and tracts are more numerous in the young animal; in the adult they are frequently found transformed into lobules and tracts of adipose tissue.

The **nerves** of the serous membranes are destined chiefly for the blood-vessels, and for the most part accompany these in their course. A few pale fibres, however, are distributed to the substance of the membrane, in which they form a plexus with large meshes: from the branches of this plexus, fibrils may be traced which unite into a somewhat finer plexus near the surface.

Recent Literature of the Lymphatic System. On Lymphatic Vessels:—*Recklinghausen*, in Stricker's Handbook, 1871; *J. Arnold*, in Virch. Arch., LXII., 1874; *Foà*, in Virch. Arch., LXV., 1875; *Tarchanoff*, in Arch. de physiol., 1875; *Flemming*, in Arch. f. mikr. Anat., XII., 1876; *Gaskell*, in Arb. d. physiol. Anst. zu Leipzig, 1876; *Dogiel*, in Arch. f. mikr. Anat., XVII., 1879.

On Lymphatic Glands:—*Bizzozero*, in Moleschott's Unters., XII. 1873; *Lodi*, in Riv. clin., 1876.

On Serous Membranes:—*Klein & Burdon Sanderson*, in Med. Centralbl., 1872; *Klein*, in Quart. J. Micr. Sci. XII., 1872 (ciliated vesicles in frog's perit.); "The Serous Membranes," 1873; and in Qu. J. Micr. Sci., 1877 (on the omentum); *Bizzozero*, in Med. Centralbl., 1874; (with *Salvioli*) in Arch. p. le sci. med., 1876, and 1877.

SYNOVIAL MEMBRANES.

These are connective tissue membranes which are found surrounding closed cavities in connection with moveable structures in certain parts, such as the joints, the elongated sheaths in which some tendons glide, and at various situations between the skin and bony prominences below it. Although they resemble serous membranes in some respects, the synovial membranes are distinguished by the nature of their secretion,

[redacted]h is a viscid glairy fluid resembling the white of an egg, named [redacted]via. From its nature it is well adapted for diminishing friction, and [redacted]eby facilitating motion.

[redacted]f a drop of synovial fluid be examined microscopically, it is found to [redacted]tain (in addition to fat-molecules) a few amœboid corpuscles, as well [redacted]cells similar to those which occur on the projections of the membrane.

[redacted]The different synovial membranes of the body are referred to three [redacted]ses, viz., *articular*, *vaginal*, and *vesicular*, or *bursal*.

[redacted]. **Articular synovial membranes,** or *Synovial capsules of [redacted]ts.*—These by their synovial secretion lubricate the cavities of the [redacted]rthrodial articulations, that is, those articulations in which the [redacted]posed surfaces glide on each other. In these cases the membrane [redacted]y be readily seen covering internally the surface of the capsular and [redacted]er ligaments which bound the cavity of the joint, and affording also [redacted] investment to any tendons or ligaments which pass through the [redacted]icular cavity, as in the instance of the long tendon of the biceps [redacted]uscle in the shoulder-joint. On approaching the articular cartilages [redacted]e membrane does not pass over them, but terminates after advancing [redacted]t a little way on their surface, with which it is here firmly adherent. [redacted]he synovial membranes, therefore, do not form closed bags lying between [redacted]e articular cartilages as was supposed by the older anatomists, for the [redacted]in part of the surfaces of the joints are not covered at all by the [redacted]embrane, nor even by a layer of epithelium-cells, prolonged from the [redacted]embrane, as some have described.

In several of the joints, folds of the synovial membrane pass across the cavity; these have been called synovial ligaments. Other processes of the membrane simply project into the cavity at various points. These are very generally cleft into fringes at their free border, upon which their blood-vessels, which are numerous, are densely distributed. The larger folds and processes often contain fat, and then are sufficiently obvious; but many of the folds are small and inconspicuous.

The fringed vascular folds of the synovial membrane were described by Havers in 1691, under the name of the *mucilaginous glands*, and he regarded them as an apparatus for secreting synovia. Rainey found that these *Haversian fringes*, as they are sometimes called, may exist in all kinds of synovial membranes, and that from the primary vascular fringes other smaller secondary processes are sent off, into which no blood-vessels enter.

2. Vaginal synovial membranes or *Synovial sheaths.*—These are intended to facilitate the motion of tendons as they glide in the fibrous sheaths which bind them down against the bones in various situations. The best-marked examples of such fibrous sheaths are to be seen in the hand and foot, and especially on the palmar aspect of the digital phalanges, where they confine the long tendons of the flexor muscles. In such instances one part of the synovial membrane forms a lining to the osseo-fibrous tube in which the tendon runs, and another part affords a close investment to the tendon. The space between these portions of the membrane is lubricated with synovia and crossed obliquely by one or more folds or duplications of the membrane named "frænа," in some parts inclosing a considerable amount of elastic tissue (Marshall).

3. Vesicular or **Bursal synovial membranes,** *Synovial bursæ*, *Bursæ mucosæ.*—In these the membrane has the form of a simple sac,

interposed, so as to prevent friction, between two surfaces
move upon each other. The synovial sac in such cases is fl
and has its two opposite sides in apposition by their inner
which is free and lubricated with synovia, whilst the outer sur
attached by areolar tissue to the moving parts between which the
placed.

In regard to situation, the bursæ may be either deep-seated or
taneous. The former are for the most part placed between a mu
its tendon and a bone or the exterior of a joint, less commonly be
two muscles or tendons: certain of the bursæ situated in the
bourhood of joints not unfrequently open into them. The subcut
bursæ lie immediately under the skin, and are found in various
of the body interposed between the skin and some firm promi
beneath it. The large bursa situated over the patella is a well-k
example of this class, but similar though smaller bursæ are foun
over the olecranon, the malleoli, the knuckles, and various other
minent parts. It must, however, be observed that, among these
taneous bursæ, some are reckoned which do not always present

Fig. 209.

Fig. 210.

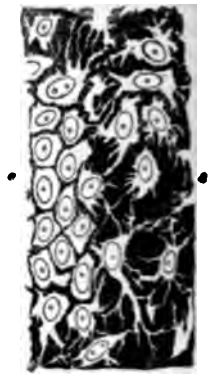


Fig. 209.—Ramified connective-tissue corpuscles, from articular synovia membrane of ox. 250 diameters. (E. A. S.)

Fig. 210.—Portion of the surface of a vaginal synovial membrane, after treatment with nitrate of silver. 250 diameters (E. A. S.).

The cell-spaces of the tissue and the nuclei of the contained cells only are represe
e, epithelioid arrangement of cells; *s*, ramified cells.

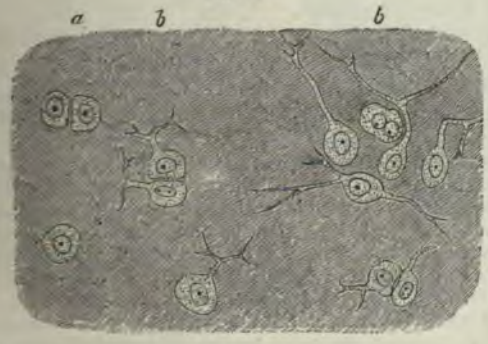
characters of true synovial sacs, but look more like mere recesses in subcutaneous areolar tissue, larger and more defined than the ne bouring areolæ, but still not bounded by an evident synovial membr These may be looked on as examples of less developed structure, fo ing a transition between the areolar tissue spaces and perfect syno cavities.

ucture of synovial membranes.—The synovial membranes are sed entirely of connective tissue with the usual cells and fibres of issue. It was formerly stated, and is still asserted by Tillmanns and , that they are lined with an epithelial layer of flattened cells, similar se lining the serous membranes, but, as was shown by Hüter, there on the synovial membranes no complete lining of the kind. s of cells may, it is true, here and there be met with which t an epithelioid appearance (fig. 210, *e*), as, indeed, we know to case in the connective tissue of other parts; but most of the -cells of the synovial membranes are of the irregularly-branched igs. 209, 210, *s*), the surface of the membrane between the cells and mes also over them being formed by the ground-substance of the tive tissue, whilst here and there small blood-vessels come close surface from subjacent parts. The cells are in many places r than in connective tissue generally. They vary much in shape erent parts, sometimes forming a network in the tissue by the moses of their ramifying processes, in other parts being rounded, ore closely arranged.

cells of the vaginal synovial membrane are often slightly elongated direction of the axis of the tendon.

articular synovial membranes pass, as before said, a certain e over the cartilages of the joints. They do not, however, end ly, but shade off gradually into the margin of the cartilage, the

Fig. 211.



1. TRANSITION OF CARTILAGE-CELLS INTO CONNECTIVE-TISSUE CORPUSCLES OF IAL MEMBRANE. ABOUT 340 DIAMETERS. FROM HEAD OF METATARSAL BONE, N. (E. A. S.)

a, ordinary cartilage cells; *b*, *b*, with branched processes.

s tissue becoming fibro-cartilage and the cells gradually losing processes and becoming transformed into cartilage-cells (fig. 211), t it is difficult to say where the one structure begins and the other This portion of the synovial membrane, or of the cartilage, is known "marginal zone;" it is best marked around the convex heads of ones, and is especially well seen near the lower margin of the (Hüter).

Haversian folds and fringes, at least the larger ones, agree in l structure with the rest of the tissue of the synovial membrane, that, as before remarked, some of them contain fat; their surface

layer contains for the most part irregularly stellate cells, except over the fat, where there is occasionally to be observed a true epithelioid covering like that of a serous membrane. The smaller non-vascular secondary fringes of Rainey (*synovial villi*) are minute finger-shaped processes projecting from the margins of the larger ones, and consist for the most part of small rounded cells with granular protoplasm and but little intercellular substance, enclosing a central strand of connective-tissue fibrils and in some cases even one or two cartilage-cells. Some of the synovial villi are entirely made up of fibro-cartilage, being altogether destitute of the covering of rounded cells (Tillmanns).

Vessels and nerves.—The blood-vessels in and immediately beneath the synovial membrane are numerous in most parts of the joints. They advance but a short way upon the cartilages, forming around the margin a vascular zone, named by W. Hunter "circulus articuli vasculosus," in which they end by loops of vessels dilated at the best part greatly beyond the diameter of ordinary capillaries (Toynbee). In the fœtus these vessels advance further upon the surface of the cartilage than in the adult. The vessels of the vaginal synovial membranes are less numerous than those of the synovial membranes of the joints.

The synovial cavities do not appear to have so close a relation to the lymphatic system as is the case with the serous cavities. For although lymphatic vessels have been described by Tillmanns and others in the synovial membranes, they have not been shown to communicate with the cavities, nor do they as a rule lie near the free surface. In this respect they differ from the blood-capillaries, which may come close up to the inner surface of the membrane.

W. Krause describes the nerves of the synovial membranes (at least those of the joints) as terminating in peculiar corpuscles allied to end-bulbs. Another observer (Nicoladoni) has traced nerves into a plexus of pale fibrils lying close under the surface of the membrane.

Development.—At the time of the formation of a joint by cleavage the tissue around it forms, in its outer part, the fibrous capsule of the joint; in its inner part, the commencement of the synovial membrane. The cartilage cells on the surfaces of the newly formed joint are at first, like those of the embryonic cartilage generally, placed closely together without matrix or intercellular substance; after a time this appears in fine lines between the cells, so that there is then presented, in silvered preparations, an epithelioid appearance. By a further development of intercellular substance the superficial cells become more separated from one another, and now possess an irregularly branched shape with communicating processes. Near the edge of the cartilage this condition is permanent, so that the marginal zone of the synovial membrane is formed *in situ* from what was originally cartilage. Nearer the centre of the articular surface, a further change takes place in the progress of development. The cells lose their processes and acquire the characters of ordinary cartilage cells, whilst the matrix between them becomes increased, and forms also a thin layer covering their surface.

Literature.—*Rainey*, Proc. R. S., 1846; *Hueter*, Virch. Arch., xxxvi.; *Albert*, in Wiener Sitzungsb., 1871; *Reyher*, The cartilages and synovial membranes of the joints, Journ. of Anat. and Physiol., 1874; *Tillmanns*, Histol. d. Gelenke, Arch. f. mikr. Anat., 1874; Lymphgef. d. Gelenke, ibid. xii., 1876; Hist. d. Synovialhäute, Arch. f. klin. Chir., 1876; *Bentzen*, Devel. of joints, Nord. med. arkiv., 1875; *Sluys* in Niederl. Arch. f. Zool., 1876; *Weichselbaum*, in Wiener Sitzungsb. lxxv., 1877.

yields them up to be poured out with the rest of the secretion—the co tained substance escaping from it either by exudation or by bursting a destruction of the cell itself. Cells filled with secreted matter may also detached, and carried out entire with the fluid part of the secretion; an in all cases, new cells speedily take the place of those which have serv their office. The fluid effused from the blood-vessels supplies mat for the nutrition of the secreting structure, besides affording the ma rials of the secretion.

Changes in the cells during activity.—Since the materials f secretion are selected or prepared by the cells it is not surprising to fi that the cells of a secreting gland differ considerably in appearan

Fig. 213.

Fig. 213.—Part of a ferment-forming gland; A at rest, B after a sho period of activity, C after a prolonged period of activity. (Langley.)

In the resting condition the cells of the gland are almost filled with granules (of zym gen). During activity these become discharged from the cells as ferment, disappearin at first from the outer part of the cell, which is thereby left clear. Finally the granul only remain near the lumen of the alveoli, and near the surfaces of the cells which ar contiguous to one another. In A and B the nuclei of the cells are obscured by th granules.

according as the gland is in a condition of rest or activity (fig. 212). In the former case the materials for secretion may have bee accumulating within the cells and may be detected within them, whereas in the latter case, if the secretion have been proceeding fo some time, the cells may be emptied of the accumulated material, and in many instances may themselves be partially or entirely destroyed, owing to the disruption of their protoplasm in the process of discharg of the secreted matter. In some glands however the accumulation of the materials of secretion within the cells does not go on to any great extent during rest, but begins with the increased activity o the gland consequent on stimulation whether natural or artificial, an proceeds up to a certain point, after which the process of discharg of the accumulated material begins. But according to Heidenhai and Langley the processes of growth of the protoplasm, formation o material for secretion, and discharge from the cell may all go o simultaneously, the material becoming formed by or from the cel protoplasm on the one hand, and discharged on the other hand int the commencement of the duct.

The material which accumulates within the cell is not always the same as th which appears in the discharged secretion. Thus in the glands which furni the digestive ferments—especially the gastric glands and the pancreas—it h

shown that the material which appears in the form of granules within the s not the pepsin and the trypsin which respectively characterise the secre- of those glands, but a precursor which is termed "zymogen," and is easily formed into the ferments by the action of certain reagents; and it is sup- that a similar change may occur during the discharge of the secretion from ells. Again in the cells which secrete mucus, the clear substance which ulates within the cells is not mucin, but a precursor of mucin, which is ed "mucigen," from the facility with which it becomes on discharge converted mucin.

is difficult to decide whether the material for secretion is formed by the conversion of a part of the protoplasm of the secreting cell, or from rials taken up from the plasma of the blood and elaborated by the agency e protoplasm. It is generally assumed that the former is the case, and that protoplasm of the cells of a secreting gland increases in amount as the first in the process of formation of the secretion. But since the materials of tion accumulate in the substance of the protoplasm it may not be always ble to determine how much of the increase of size of the cell is due to a th of the protoplasm itself, and how much to the accumulation of the rials of secretion, either entirely or only partially elaborated, within it. It obable that the reticular structure which the protoplasm of many secreting exhibits is caused by the accumulation within it of the material of secretion granular or globular form; the closely-arranged globules reducing the proto- m in which they are embedded to the condition of a fine spongework.

he secretory changes which have heen noticed by various observers in the of different glands will be more fully described when the several glands are ially treated of.

Modifications in form of the secreting surface.—A secreting paratus, effectual for the purpose which it is destined to fulfil, y thus be said essentially to consist of a layer of secreting cells

Fig. 214.

Fig. 214.—PLAN OF A SECRETING MEMBRANE (Sharpey).

a, membrana propria or basement-membrane; *b*, epithelium, composed of secreting ls; *c*, layer of capillary blood-vessels.

overing a free surface, whilst a layer of finely ramified blood-vessels spread out close to the attached ends of the cells, with some- times a basement membrane between the two. But whilst the structure may remain essentially the same, the configuration of the secreting surface presents various modifications in different secreting organs. In some cases, the secreting surface is plain (fig. 214), or, at least, expanded, as in various parts of the serous, synovial, and mucous membranes, which may be looked on as examples of comparatively simple forms of secreting apparatus; but, in other instances, and par- ticularly in the special secretory organs named glands, the surface of the secreting membrane is variously involved and complicated. An obvious effect of this complication is to increase the extent of the secreting surface in a secreting organ within a given bulk, and thus augment the quantity of secretion yielded by it. No connection has been clearly shown to exist between the *quality* of the secretion and the particular configuration, either internal or external, of the organ;

on the other hand, we know that the same kind of secretion t
derived from a complex organ in one animal, may be produced
apparatus of most simple form in another.

There are two principal modes by which the surface of the me
is so increased in extent, namely, by rising or protruding in form
prominent fold or some otherwise shaped projection (fig. 215, *d*,
by retiring, in form of a recess (fig. 216, A, *g*, *h*).

The first-mentioned mode of increase, or that by *protrusion*, i
that which is most generally followed in nature, still it is not w
example, and, as instances, may be cited the Haversian fringes
synovial membranes and the urinary organ of molluscs. In these
the membrane assumes the form of projecting folds, which, for
sake of further increase of surface, may be again plaited and
plicated, or cleft and fringed, at their borders (fig. 215, *e*, *f*).

The augmentation of the secreting surface by *recession* or *inv*
of the membrane, in the form of a cavity, is, with few exceptions,
generally adopted in the construction of secreting glands. The
degree is represented by a simple recess (fig. 216, *g*, *h*), and
recess, formed of secreting membrane, constitutes a *simple gland*.

Fig. 215.

Fig. 215.—PLAN TO SHOW AUGMENTATION OF SURFACE BY FORMATION OF PROCESSES (Sharpey).

a, *b*, *c*, as in preceding figure; *d*, simple, and *e f*, branched or subdivided proc

shape of the cavity may be tubular (*g*) or saccular (*h*): of these
kinds of simple gland the former is by far the more common. Exam
of simple glands are found at the back of the tongue, in the intestines,
in the olfactory membrane. The secreting surface may be increased,
a simple tubular gland, by mere lengthening of the tube, in wh
case, however, when it acquires considerable length, the tube is coiled
into a ball (fig. 216, *i*), so as to take up less room, and adapt itself
receive compactly ramified blood-vessels. The sweat-glands of the sk
are instances of simple glands formed of a long convoluted tube. B
the chief means observed of further increasing the secreting surface is
by the subdivision, as well as extension, of the cavity, and when this
occurs the gland is said to be *compound*. There is, however, a condition
sometimes met with, in which the sides or extremity of a simple tube or
sac merely become pouched or loculated (fig. 216, *k*, *l*).

In the compound glands, the divisions of the secreting cavity may
assume a tubular or a saccular form, and this leads to the distinction of
these glands into the "tubular," and the "saccular," or "racemose."
Glands which are intermediate in structure between these types are also
met with, and have received the name of "acino-tubular" glands, since
in them the terminal saccules or acini present a more or less tubular
form.

The *racemose* compound glands (fig. 216, C) contain a multitude of

…les, opening in clusters into the extremities of a branched tube, …d the excretory duct. The saccules are rounded, pyriform or …ble-shaped. They are often rather filled than lined by secreting …; they are arranged in groups, round the commencing branches of …duct, into which they open (fig. 216, c, *n*) ; or it might with equal …n be said that the branches of the duct are distended into clusters of …ular dilatations. The ultimate branches of the duct open into larger …ches (*o*), these into larger again, till they eventually terminate in … or more principal excretory ducts (*m*), by which the secretion is …ed out of the gland. It is from the clustered arrangement of their …nate vesicular recesses that these glands are named "racemose" or …e-like ; and they, for the most part, have a distinctly lobular …cture. The lobules are held together by the branches of the duct

Fig. 216.

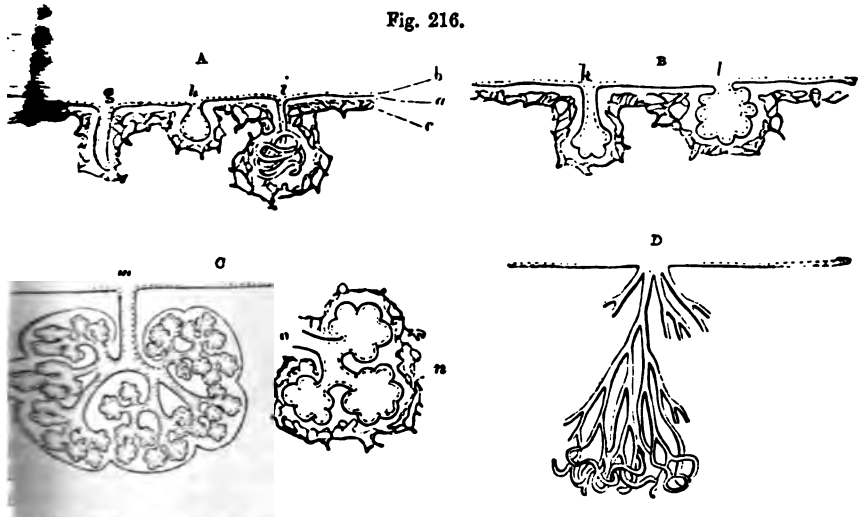


Fig. 216.—Plans of extension of secreting membrane, by inversion or recession. (Sharpey.)

A, simple glands, viz., *g*, straight tube ; *h*, sac ; *i*, coiled tube. B, simple glands with loculated walls ; *k*, of tubular form ; *l*, saccular. C, racemose, or saccular compound gland ; *m*, entire gland, showing branched duct and lobular structure ; *n*, a lobule, detached with *o*, branch of duct proceeding from it. D, compound tubular gland.

to which they are appended, and by interlobular connective tissue which also supports the blood-vessels in their ramifications. The larger lobules are made up of smaller ones, these of still smaller, and so on for several successive stages. The smallest lobules (*n*) consist of two or three groups of saccules, with a like number of ducts, joining into an immediately larger ramuscule (*o*), which issues from the lobule ; and a collection of the smallest lobules, united by connective tissue and vessels, forms one of the next size, which, too, has its larger branch of the duct, formed by the junction of the ramuli belonging to the ultimate lobules. In this way, the whole gland is made up, the number of its lobules and of the branches of its duct depending on its size ; for whilst some glands of this kind, like the

parotid, consist of innumerable lobules, connected by a large and many-branched duct, others, such as some of the sebaceous glands of the skin, are formed of but two or three ultimate lobules, or even of a single one. In fact, a small racemose gland resembles a fragment of a larger one.

The smallest lobules were originally called *acini*, a term which is now generally used to denote the saccular recesses in the lobules. These are also termed *alveoli*.

The ultimate saccules of a racemose gland are lined, and sometimes almost filled by the secreting cells, a cavity being left in the centre communicating with the excretory duct (fig. 217). In some cases minute canals lead from the central cavity between the cells, and these may aid in the conveyance of the secretion of the latter into the

Fig. 217.

Fig. 217.—Section of a racemose gland, showing the commencement of a duct in the alveoli. Magnified 425 diameters (E. A. S.).

a, one of the alveoli, several of which are in the section shown grouped around the commencement of the duct. *a'*; *a'*, an alveolus, not opened by the section; *b*, basement membrane in section; *c*, interstitial connective tissue of the gland; *d*, section of a duct which has passed away from the alveoli, and is now lined with characteristically-striated columnar cells: *s*, semilunar group of darkly-stained cells at the periphery of an alveolus.

cavity. It is doubtful whether these intercellular canals have proper walls or are merely formed by the juxtaposition of grooves on the adjacent sides of the cells. Further, the flattened cells which compose the basement-membrane may send delicate lamellar processes between the alveolar cells, among which they form a sustentacular network (Boll, Ebner).

Many glands, yielding very different secretions, belong to the racemose class. As examples, it will be sufficient to mention the salivary, lachrymal, and mammary glands, and many of the small glands which open into the mouth, fauces, and windpipe; but some even of these are intermediate in structure between the true racemose and the tubular glands.

Of the *tubular* compound glands, the most characteristic examples are the testis and kidney. In these the tubular ducts divide again and again into branches, which, retaining their tubular form, are greatly lengthened out. The branches of the ducts are formed, as usual, of a tunica propria or basement-membrane (*membrana propria*), lined by epithelium, and in contiguity, by its outer surface, with capillary blood-vessels. By the multiplication and elongation of the tubular branches the great extent of secreting surface is obtained, the tubes being usually rolled up into a compact mass, which is traversed and held together by blood-vessels, and sometimes, also, divided into lobules and supported, as in the testis, by fibrous partitions, derived from the inclosing capsule of the gland. In consequence of their intricately involved arrangement, it is sometimes difficult to find out how the tubular ducts are disposed at their extremities. In the testis some are free, and simply closed without dilatation, and others anastomose with neighbouring tubes, joining with them in the form of loops; in the kidney, little round tufts of fine blood-vessels project into terminal dilatations of the ducts, but without piercing the basement membrane.

The mammalian liver does not precisely agree in structure with either of the above classes of compound glands. Its secreting cells are collected into small polyhedral masses termed the hepatic lobules, pervaded by a network of capillary blood-vessels; and the ducts begin within the lobules, in the form of a network of exceedingly fine channels which run between the sides of contiguous cells.

Besides blood-vessels, the glands are furnished with lymphatics, which in most compound glands proceed from interstitial lymphatic spaces which surround the alveoli as already stated (p. 203). Branches of nerves have also been followed for some way into these organs; and that an influence is exerted on secreting organs through the medium of the nervous system, is shown by the fact, that the flow of secretion in several glands is affected by mental emotions, and that the flow of secretion from many glands may be brought on by direct or reflex stimulation of their nerves. In some cases also an increased accumulation of the materials of secretion within the cells, may thus be produced. Moreover, fine non-medullated nerve-fibres have in several instances been described as entering between the cells of the alveoli; and in the salivary glands, Pflüger has affirmed a direct passage of nerve-fibres, both medullated and non-medullated, into the secreting cells. His observations, however, have not been confirmed by other inquirers, although Kupffer has described a similar connection between nerve-fibres and secreting cells in the salivary glands of insects.

Uniting the several parts of a compound gland is a certain amount of interstitial connective tissue, which varies in character in different glands, being in some more fibrous, in others more cellular, and in others again being represented by retiform tissue.

Some glands have a special envelope, as in the case of the kidney and testis.

The ducts of glands ultimately open into cavities lined by mucous membrane, or upon the surface of the skin. They are sometimes provided with a reservoir, in which the secretion is collected, to be discharged at intervals. The reservoir of the urine receives the whole of the secreted fluid; in the gall-bladder, on the other hand, only a part of the bile is collected. The vesiculæ seminales afford another example of these

appended reservoirs. The ducts are constructed of a basement-me and lining of epithelium, and in their smaller divisions there is more ; but in the larger branches and trunks, a coat, composed nective tissue, with which in some cases involuntary muscular fi introduced, is added. In the ducts of the sweat glands, the n fibres lie between the basement-membrane and the epitheliun epithelium-cells are usually flattened at the commencement of t where these emerge from the alveoli, and are columnar in the the duct. In some glands the columnar cells of the ducts exh peculiar striated appearance before referred to (see p. 4), in t of the cell next to the basement-membrane, and the alveolar c also exhibit a similar appearance, but far less distinctly.

Mechanism of the discharge of secretion from a gland.—Although no pendent ultimately upon physical and chemical conditions, it is not kn cisely in what way the discharge of secretion from the gland-cells, and e from the gland is effected. The forces which produce the discha however, considerable, and are influenced as we have seen through the system. In the cutaneous glands of the frog Stricker and Spina hav that irritation of the nerves is followed by swelling and enlargemen previously flattened cells of the gland, and that this enlargement can charge of secretion from the mouth of the duct. The swelling is produc accumulation of fluid, derived from the plasma of the blood, within the when these come again to the condition of rest and resume the flatten the fluid is supposed to pass from them into the cavity of the alveolus, with it the materials of secretion extracted from the cells. If the gl again stimulated the same process is gone through, and in this way it is an intermittent discharge may be caused. There is no evidence, however that similar changes occur in other glands, nor is it explained how it that the water of the plasma should pass into the cells only under the of excitation.

The discharge from the ducts of a gland is partly due to the *vis-a-ter* accumulating secretion, partly to the peristaltic contraction of the tissue in the wall of the duct (where this tissue exists).

Recent Literature.—The following authors have written more recent structure of secreting glands and on the changes which their cells under secretion :—*Gianuzzi*, in Ber. d. sächs. Gesellsch. d. Wissensch., 1862 ; *Boll* f. mikr. Anat., 1868 and 1869 ; *R. Heidenhain*, Studien d. phys. Inst. u 1868 ; Pflüger's Arch., 1875, and article "Absonderung," in Hermann's Hand *Ebstein*, in Arch. f. mikr. Anat., 1870 ; *Pflüger*, Article "Salivary G Stricker's Handbook, 1871 ; *Ebner*, in Arch. f. mikr. Anat., 1872, and Die ac der Zunge, 1873 ; *Kupffer*, in Ludwig's Festgabe, 1874 ; *Watney*, in Proc. 1874 ; *Swiecicki*, in Pfl. Arch., 1876 ; *Lavdorsky*; *Nussbaum* ; *Partsch*, in Arc Anat., 1877 ; *Kühne u. Lea*, in Heidelberg Verhandl., 1877 ; *Grützner*, in 1879 ; *Langley*, in Journal of Physiology, 1879 ; with *Sewall*, in the same Jou in Phil. Trans., 1881.

MUCOUS MEMBRANES.

These membranes, unlike the serous, line passages and cavities which communicate with the exterior, as well as recesses, ducts and receptacles of secretion, which open into such passages. They are habitually subject either to the contact of foreign substances introduced into the body, such as air and aliment, or of various secreted or excreted matters, and hence their surface is coated over and protected by mucus, a fluid of a more consistent and tenacious character than that which moistens the serous membranes.

The mucous membranes of several different or even distant parts are continuous, and they may all, or nearly all, be reduced to two great divisions, namely the *gastro-pneumonic* and *genito-urinary*. The former covers the inside of the alimentary and air-passages as well as the less considerable cavities communicating with them. It may be described commencing at the edges of the lips and nostrils, where it is continuous with the skin, and proceeding through the nose and mouth to the throat, whence it is continued throughout the whole length of the alimentary canal to the termination of the intestine, there again meeting the skin, and also along the windpipe and its numerous divisions as far the air-cells of the lungs, to which it affords a lining. From the nose the membrane may be said to be prolonged into the lachrymal passages, extending up the nasal duct into the lachrymal sac and along the lachrymal canals until, under the name of the conjunctival membrane, it spreads over the fore part of the eyeball and inside of the eyelids, on the edges of which it meets with the skin. Other offsets from the nasal part of the membrane line the frontal, ethmoidal, sphenoidal and maxillary sinuses, and from the upper part of the pharynx a prolongation extends on each side along the Eustachian tube to line that passage and the tympanum of the ear. Besides these there are offsets from the alimentary membrane to line the salivary, pancreatic, and biliary ducts, and the gall-bladder. The *genito-urinary* membrane invests the inside of the urinary bladder and the whole tract of the urine in both sexes, from the interior of the kidneys to the orifice of the urethra, also the seminal ducts and vesicles in the male, and the vagina, uterus and Fallopian tubes in the female.

By one surface the mucous membranes are attached to the parts which they line or cover, by means of areolar tissue, named "submucous," which differs greatly in quantity as well as in consistency in different parts. The connection is in some cases close and firm, as in the cavity of the nose and its adjoining sinuses; in other instances, especially in cavities subject to frequent variation in capacity, like the gullet and stomach, it is lax and allows some degree of shifting of the connected surfaces. In such cases as the last-mentioned the mucous membrane is accordingly thrown into folds when the cavity is narrowed by contraction of the exterior coats of the organ, and of course these folds, or *rugæ* as they are named, are effaced by distension. But in certain parts the mucous membrane forms permanent folds, not capable of being thus effaced, which project conspicuously into the cavity which it lines. The best-marked example of these is presented by the *valvulæ conniventes* seen in the small intestine. These, as is more fully described in the special anatomy of the intestines, are crescent-shaped duplicatures of the

membrane, with connecting areolar tissue between their laminæ, which are placed transversely and follow one another at very short intervals along a great part of the intestinal tract. The chief use of the valvulæ conniventes is doubtless to increase the surface of the absorbing mucous membrane within the cavity.

In most situations the mucous membranes are nearly opaque or only slightly translucent. They possess no great degree of tenacity and but little elasticity, and hence are readily torn by a moderate force. The redness which they commonly exhibit during life, and retain in greater or less degree in various parts after death, is due to the blood contained in their vessels. The degree of redness is greater in the fœtus and infant than in the adult. It is greater too in certain situations; thus, of the different parts of the alimentary canal, it is most marked in the stomach, pharynx, and rectum.

Structure.—A mucous membrane is composed of *corium* and *epithelium*. The *epithelium* covers the surface. The membrane which remains after its removal is named the *corium*, as in the analogous instance of the true skin.

The **epithelium** (fig. 218, *e*) is the most constant part of a mucous membrane, being continued over certain parts to which the other constitutents of the membrane cannot be traced, as over the alveoli of the lungs, and the front of the cornea of the eye. It may be scaly and stratified as in the mouth and throat, columnar as in the intestine, or ciliated as in the respiratory tract and uterus. When a mucous membrane is covered with an epithelium of the scaly and stratified variety, the mucus which moistens its surface is derived from glands in the membrane, which are lined with columnar and polyhedral secreting cells; but when a columnar epithelium covers the surface, a large part of the mucus is formed in the cells of this layer, and the glands of the membrane are frequently devoted to the elaboration of some special secretion.

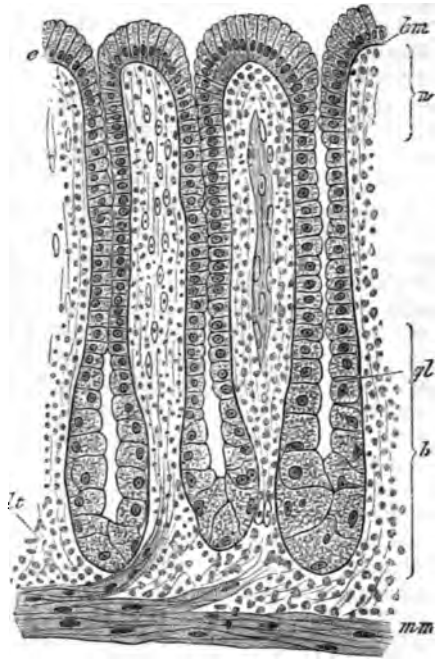
Those columnar cells which are especially concerned in the production of mucus often become greatly distended with the accumulated mucigen into the shape of a goblet or chalice, and this may in many be seen to have become exuded from the free and apparently open end of the cell as a droplet of mucus (see p. 44). A certain number of these *goblet-* or *chalice-cells* are almost always to be found amongst the ordinary columnar cells. It is somewhat uncertain whether after discharge of their secretion they become converted into ordinary columnar cells, or whether they permanently maintain the chalice-like form, their cavity becoming again filled with secretion during rest. If the latter is the case the cells in question are analogous to the uni-cellular glands which are met with in the integument of some of the lower animals (leech).

The **corium** of a mucous membrane consists of connective tissue, either simply areolar or containing a large intermixture of lymphoid tissue. It is usually bounded next the epithelium by a basement membrane (fig. 218, *bm*), and next the submucous tissue by a thin layer of non-striated muscular tissue termed the *muscularis mucosæ* (*mm*).

The *basement membrane* is not everywhere demonstrable, but where it is well marked it appears in section as a thin line immediately underlying the epithelium. Viewed on the flat and with the superjacent epithelium removed, the membrane in question seems at first sight homogenous; but treatment with nitrate of silver brings to view the

lines of the flattened cells of which it is in reality composed. It is always a complete membrane, for in some parts the cells composing it, instead of adhering closely by their edges, intercommunicate by branching processes so as to form a network instead of a continuous membrane. The basement membrane follows all the eminences and depressions of the surface of the mucous membrane, dipping down to take part in the formation of the wall of the glands, and passing over the raised villi and other prominences.

Fig. 218.



. 218.—Section of mucous membrane from the stomach of the kangaroo. Magnified about 260 diameters (E. A. S.).

e, columnar epithelium of the surface, continued into the neck, *n*, of simple tubular glands, *gl*; but becoming at first cubical, and then polyhedral towards the base, *b*, of the glands; *lt*, lymphoid tissue of the corium, seen also between the glands; *bm*, basement membrane, bounding the corium superficially; *mm*, muscularis mucosæ, bounding the mucous membrane at its attached surface, and sending small bundles of plain muscular tissue between the glands. The commencement of a lymphatic vessel is shown between two of the glands, but its connection with deeper lymphatics was not seen. The blood-vessels of the membrane are not represented.

The *muscularis mucosæ* is the deepest part of a mucous membrane, but it is not everywhere present. It is best developed in the mucous membrane of the alimentary canal, in some parts of which it seems to consist of two layers, in the one of which the fibres are longitudinal, in the other circular in direction. From its inner surface muscular bundles pass inwards into the thickness of the mucous membrane, passing between the glands contained within it, and even into its prominences, reaching in many cases to reach and become attached to the basement-membrane covering them. The muscularis mucosæ is a part therefore of the mucous membrane, and is not to be confounded with the muscular coat proper, which forms a separate layer in most of the hollow viscera.

The *connective tissue layer* or *corium proper* varies much in structure in different parts. In some situations, as in the gullet, bladder, and vagina, the filamentous connective tissue is abundant, and extends throughout its whole thickness, forming a continuous and tolerably compact web, and rendering the mucous membrane of those parts comparatively stout and tough. In the stomach and intestines, on the other hand, where the membrane is pervaded by tubular glands, the tissue between these is chiefly retiform or lymphoid tissue (fig. 218, *lt*) with but

few white and elastic fibres, and hence in these situations the membrane, although thicker, is far less firm and tough than in parts where much of the white connective tissue is found. In other mucous membranes transitions are met with between these two extremes.

It frequently happens that in certain circumscribed places the lymphoid tissue is greatly increased in amount, and becomes densely packed with lymphoid cells. In this way the so-called *solitary glands, follicles* or *nodules* are produced. If there be many lymphoid nodules adjacent to one another, so as to make up a localized patch, a so-called agminated gland is formed, or if massed together more thickly, a lymphoid organ like the tonsil. These collections of lymphoid tissue, which may if large extend, on the one hand, down into the submucous tissue, and on the other, upwards into the epithelium, have been already referred to (p. 213), and will be more particularly described when the several parts in which they occur come under consideration.

Blood-vessels are abundant in most mucous membranes. The branches of the arteries and veins, dividing in the submucous tissue, send smaller branches into the corium, which divide to form a network of capillaries in the latter. This capillary network lies immediately beneath the epithelium, or the basement-membrane when this is present, advancing into the villi and papillæ to be presently described, and surrounding the tubes and other glandular recesses. The **lymphatics** also form networks of cleft-like vessels in the mucous membrane, which communicate with plexuses of larger valved vessels in the submucous tissue ; they commence either by blind diverticula, as in the villi, or in the form of a superficial network, which is almost always more deeply placed than the network of blood-capillaries. The lymphatic vessels often form sinus-like dilatations around the bases of the lymphoid nodules.

The **nerves** of mucous membranes seem chiefly to be distributed to the muscularis muscosæ where this exists. Before proceeding to their destination they are in many parts collected together to form a gangliated plexus in the sub-mucous tissue, such as the plexus of Meissner in the alimentary canal. Some nerves pass however to the epithelium and terminate between the epithelial cells ; at least this has been shown to be the case in the stratified epithelium which covers the mucous membrane of the palate in the rabbit, and in that which lines the vagina of the same animal.

Papillæ and villi.—The free surface of the mucous membranes is in some parts plain, but in others is beset with little eminences named papillæ and villi. The *papillæ* are best seen on the tongue ; they are small processes of the corium, mostly of a conical or cylindrical figure, containing blood-vessels and nerves, and covered with epithelium. Some are small and simple, others larger and covered with secondary papillæ. They serve various purposes ; some of them no doubt minister to the senses of taste and touch, many appear to have chiefly a mechanical office, while others would seem to give greater extension to the surface of the corium for the production of a thick coating of epithelium. The *villi* are most fully developed on the mucous coat of the small intestines. Being set close together like the pile of velvet, they give to the parts of the membrane which they cover the aspect usually denominated "villous." They are in reality little elevations or processes of the corium, covered with epithelium, and

taining bloodvessels and lacteals, which are thus favourably disposed absorbing nutrient matters from the intestine. The more detailed scription of the papillæ and villi belongs to the special anatomy of the rts in which they occur.

In some few portions of the mucous membranes the surface is marked th fine ridges which intersect each other in a reticular manner, and inclose larger and smaller polygonal pits or recesses. This peculiar racter of the surface of the membrane, which has been termed alveolar," is seen very distinctly in the gall-bladder, and on a finer le in the vesiculæ seminales; still more minute alveolar recesses with tervening ridges may be discovered with a lens on the mucous mbrane of the stomach.

Glands of mucous membranes.—Many, indeed most, of the glands the body pour their secretions into the great passages lined by mucous membranes; but there are certain small secreting glands which may be id to belong to the membrane itself, inasmuch as they are found in mbers over large tracts of that membrane, and yield mucus, or special cretions known to be formed in particular portions of the membrane. Omitting local peculiarities the glands referred to may be described as of two kinds, viz.:—

I. *Tubular glands.*—These are minute tubes formed by recesses or inversions of the basement membrane, and lined with epithelium (fig. 218, *gl*). They are usually placed perpendicularly to the surface, and often very closely together, and they constitute the chief substance of the mucous membrane in those parts where they abound, its thickness depending on the length of the tubes, which differs considerably in different regions. The tubes open by one end on the surface; the other end is closed, and is either simple or cleft into two or more branches. The tubular glands are abundant in the stomach, and in the small and large intestines, where they are comparatively short and known as the crypts of Lieberkühn. They exist also in considerable numbers in the mucous membrane of the uterus.

II. *Small compound glands.*—Under this head are here comprehended minute compound glands of the racemose or of the acino-tubular kind, with branched ducts of various lengths, which open on the surface of the membrane. Numbers of these, yielding some a mucous, others a more albuminous or serous secretion, open into the mouth and windpipe. To the naked eye they have the appearance of small solid bodies, often of a flattened lenticular form, but varying much both in shape and size, and placed at different depths below the mucous membrane on which their ducts open. The glands of Brunner, which form a dense layer in the commencing part of the duodenum, belong to this category.

Mucus—the secretion which moistens the surface of a mucous membrane—is a viscid transparent fluid, which when examined by the microscope is generally found to contain, besides detached epithelium cells, rounded cells named mucus-corpuscles, which closely resemble the pale corpuscles of the blood, and are probably identical with them (having wandered either from the vessels or from the lymphoid tissue of the membrane). The chief organic constituent of mucus—mucin—is precipitated from the fluid by the addition of acids.*

* **The several mucous membranes are described more in detail when the organs of which they form a part are treated of, and the works which refer to them may then also be mentioned most appropriately.**

THE SKIN.

The skin consists of the cutis vera or corium, and the cutic
epidermis.

The **Epidermis, Cuticle, or Scarf-Skin** belongs to the cla
stratified epithelia, the general nature of which has been already
sidered. It forms a protective covering over every part of the true

Fig. 219.

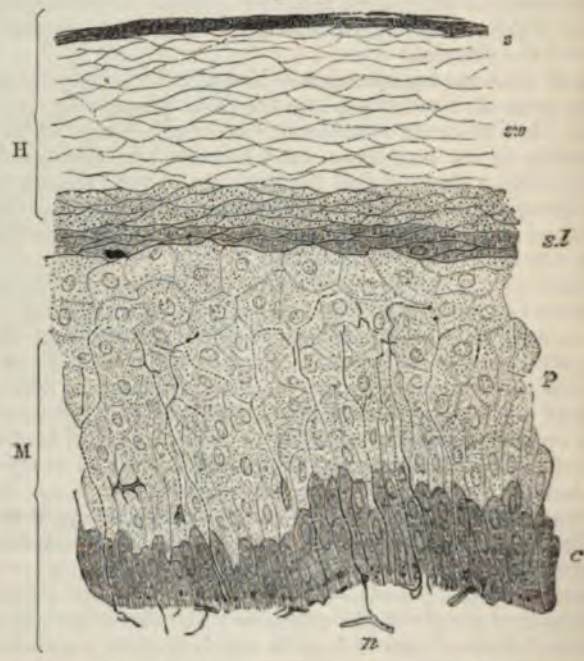


Fig. 219.—Section of epidermis from the human hand. Highly magnified (Ra

H, horny layer, consisting of *s*, superficial horny scales ; *sw*, swollen-out horny
s.l, stratum lucidum ; *M*, rete mucosum or Malpighian layer, consisting of *p*, p
cells, several rows deep ; and *c*, elongated cells forming a single stratum near the c
The granular cells of Langerhans, which lie just below the stratum lucidum, are not s
n, part of a plexus of nerve-fibres in the superficial layer of the cutis vera. Fro
plexus, fine varicose nerve-fibrils may be traced passing up between the cells
Malpighian layer.

The thickness of the cuticle varies in different parts of the su
measuring in some places not more than $\frac{1}{250}$th, and in other
as much as $\frac{1}{25}$th of an inch (about a millimeter), or even more tha
in some individuals. It is thickest in the palms of the hands
soles of the feet, where the skin is much exposed to intermittent pre
and it is not improbable that such pressure may serve to stimulat
subjacent true skin to a more active formation of epidermis ; bu
difference does not depend immediately on external causes, for it i
marked even in the fœtus.

The more firm and transparent superficial part, or horny layer,

epidermis, may be separated after maceration from the deeper, softer, more opaque, and recently formed part, which constitutes what is called the Malpighian layer, or *rete mucosum*.

The under or attached surface of the cuticle is moulded on the adjoining surface of the corium, and, when separated by maceration or putrefaction, presents impressions corresponding exactly with the papillary or other eminences, and the furrows or depressions of the true skin; the more prominent inequalities of the latter are marked also on the outer surface of the cuticle, but less accurately. Fine tubular prolongations of the cuticle sink down into the ducts of the sweat-glands, and are often partially drawn out from their recesses when the cuticle is detached, appearing then like threads proceeding from its under surface.

Structure.—The cuticle is made up of cells agglutinated together in many irregular layers. The deepest cells are elongated in figure, and placed perpendicularly on the surface of the corium (fig. 219 *c*, and fig. 224); they are denticulate at their lower ends, and fit into corresponding fine denticulations of the corium. The perpendicular cells generally form one stratum; above them are cells of a more rounded or polyhedral shape (*p*). These, as first shown by Max Schultze and Virchow, are marked on their surface with numerous ridges and furrows or are covered

Fig. 220.

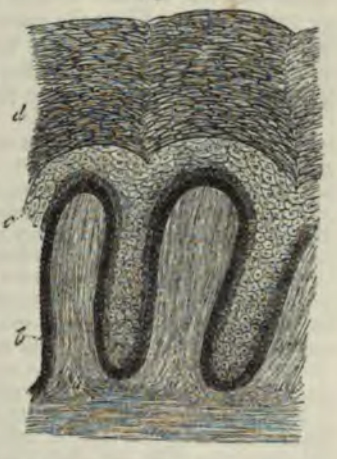


Fig. 220.—Skin of the Negro, vertical section, magnified 250 Diameters (Kölliker).

a, *a*, cutaneous papillæ; *b*, undermost and dark-coloured layer of oblong vertical epidermis-cells; *c*, mucous or Malpighian layer; *d*, horny layer.

with minute spines. The spines and ridges of neighbouring cells do not, however, interlock one with another as was at first supposed, but on the contrary, meet at their summits so as to leave between the cells fine channels through which it is conceived nutrient plasma may be conducted to the cells (Bizzozero). These so-called "prickle-cells" form several strata; above, they become gradually more flattened, conformably to the surface, until a layer is reached in which the outlines of the cells, which are two or three deep, are indistinct, so that in section they appear to form a clear almost homogeneous layer (*stratum lucidum*, Oehl; fig. 219, *s.l*). Immediately below the stratum lucidum a layer, often incomplete, of granular-looking, flattened cells is usually to be seen (Langerhans). The granules in these cells are composed of a peculiar matter staining deeply with carmine, and they are thought by some to have an intimate relation to the formation of the horny substance in the more superficial cells. Immediately above the stratum lucidum, which may be looked upon as the commencement of the horny layer of the epidermis, is a stratum of considerable thickness in which the cells are much enlarged, and the nuclei in many cases no longer visible (*sw*): towards the surface they pass into

the hard flattened scales (*s*) which are to be thrown off by desquamation. As the cells change their form, they undergo chemical and physical changes in the nature of their contents; for in the deeper layers they consist of a soft, granular, protoplasmic matter, soluble in acetic acid, whilst the superficial ones are transparent, dry, and horny, and are not affected by that reagent. These dry hard scales may be made to reassume their cellular form, by exposure for a few minutes to a solution of caustic potash or soda, and then to water. Under this treatment they are softened by the alkali, and distended by imbibition of water.

Many of the cells of the cuticle contain pigment-granules, and often give the membrane more or less of a tawny colour, even in the white races of mankind; the blackness of the skin in the negro depends entirely on the cuticle. The pigment is contained principally in the cells of the deep layer or rete mucosum (fig. 220), and appears to fade as the cells approach the surface, but even the superficial part possesses a certain degree of colour.

In the intercellular channels of the Malpighian layer lymph-corpuscles, rounded or branched, are occasionally observed. They are in all probability derived from the subjacent corium.

Nerves.—Fine varicose nerve-fibrils pass up into the epidermis, penetrating between the cells of the Malpighian layer (fig. 219), where they undergo a certain amount of ramification. The branches do not unite with one another to form a network, but end in knob-like swellings or varicosities. With the growth and displacement of the cells between which they are placed, these varicosities become, according to Ranvier, continually detached from the end of the fibrils, the latter meanwhile growing constantly to supply the place of the detached portions.

In the skin covering the snout of certain animals (*e.g.* mole) the nerves end in peculiar terminal organs (Eimer), formed of thickenings of the epidermis, the nerve-fibres passing as an elongated bunch of closely set, somewhat zigzag, varicose, unbranched fibrils between the epidermis-cells. Besides these fibrils there are others at the periphery of the organ which are less closely arranged, and terminate in branched extremities as in other parts of the epidermis.

Merkel has described the nerves of the epidermis as ending in pyriform cells (tactile cells) placed between the ordinary epithelial cells; and others have thought that the nerves could be traced to stellate cells in the interstitial spaces, but improved methods of staining with chloride of gold which have been employed in the investigation would seem to render it probable that the termination of the nerve-fibrils in the cuticle is always free as above described.

Formation and growth of Epidermis.—In the earliest condition of the embryo there is a special layer of cells, the ectoderm or epiblast, set aside chiefly for the production of the epidermis; and it is probable, that the subsequent generations of epidermic cells by which the tissue is throughout life maintained, are derived by unbroken descent from the original embryonic stratum. At first the cells form a single columnar layer, but by division of its cells a horny layer early makes its appearance, being represented at first by but a single layer of large polygonal cells, covering the layer of smaller and more columnar cells (Kölliker). The latter soon divide again and produce a second row of rounded cells superficial to them, and the increase of thickness which is thus begun continues by further division of cells in the deeper layers, so that before long the Malpighian layer has become extremely well marked. Meanwhile its more superficial cells, undergoing a chemical transformation and becoming flattened out, have been added on to the under surface of the horny layer, and this change proceeds until the mucous and horny layers are about of equal thickness. After a time the superficial cells of the horny layer begin to desquamate, and this process goes on during the rest of fœtal life, the cast-off scales appearing partly in the liquor amnii, and also,

mixed with the secretion of the sebaceous glands, forming the so-called vernix caseosa covering the whole surface of the fœtus.

The pigment of the Malpighian layer in the coloured races of mankind frequently does not appear until a day or two after birth.

The growth of epidermis continues throughout life. The cells of the Malpighian layer are constantly undergoing multiplication, and the new cells thus produced push outwards those which are previously formed. The more superficial cells of the Malpighian layer are thus continually passing on to reinforce the horny layer, the cells as they proceed outwards becoming flattened and transformed into horny matter. This change seems to occur quite abruptly when the stratum lucidum is reached; beyond this the cells again swell out somewhat, until on reaching the most superficial layers they are entirely transformed into structureless horny scales which are constantly undergoing desquamation.

There is reason to suppose that the regeneration of epidermis, when a portion has been removed by a blister or wound of any kind, takes place, like its growth, solely from cells of the Malpighian layer. If the whole of the epidermis has been destroyed or removed over an extensive surface, the process of regeneration is very slow, since the new covering has to grow in from the epidermis at the margins of the wound. But if the deeper cells have not been wholly removed the regeneration may start from the places where any of them still remain, and the formation of the new covering is proportionately quicker. In the operation of skin-grafting so-called, the surgeon endeavours to transplant from a healthy portion of skin small pieces of the epidermis, including its deeper layers, to the denuded surface: if the operation succeed, each such graft acts as a centre from which the new formation of epidermis may spread, and in this way the raw surface may be much more speedily covered.

The **True Skin, Cutis Vera, Derma,** or **Corium,** is a sentient and vascular fibrous texture. It is covered and defended, as already explained, by the non-vascular cuticle, and is attached to the parts beneath by a layer of areolar tissue, named "subcutaneous," which, excepting in few parts, contains fat, and has therefore been called also the "panniculus adiposus" (fig. 221, *d*). The connection is in many parts loose and moveable, in others close and firm, as on the palmar surface of the hand and the sole of the foot, where the skin is fixed to the subjacent fascia by numerous stout fibrous bands, the space between being filled with a firm padding of fat. In some regions of the body the skin is moved by striated muscular fibres, which may be unconnected with fixed parts, as in the case of the orbicular muscle of the mouth, or may be attached beneath to bones or fasciæ, like the other cutaneous muscles of the face and neck, and the short palmar muscle of the hand.

Structure.—The cutis vera is made up of an exceedingly strong and tough framework of interlaced connective tissue fibres. The fibres are chiefly of the white variety, such as constitute the main part of the fibrous and areolar tissues, and are arranged in stout interlacing bundles, except at and near the surface, where the texure of the corium becomes finer and closer. With these are mixed elastic fibres, which vary in amount in different parts, and connective tissue corpuscles, which are often flattened up against the bundles of white fibres. Towards the attached surface the texure becomes much more open, with larger and larger meshes, in which lumps of fat and the sweat glands are lodged; and thus the fibrous part of the skin, becoming more and more lax and more mixed with fat, blends gradually with the subcutaneous areolar tissue.

In consequence of this gradual transition of the corium into the subjacent tissue, its thickness cannot be assigned with perfect precision.

As a general rule, it is thicker on the posterior aspect of the head, and trunk, than in front; and thicker on the outer than on the side of the limbs, and as well as the cuticle, it is remarkably th the soles of the feet and palms of the hands. The skin of the fe thinner than that of the male.

The skin is generally said to measure from $\frac{1}{25}$th of an inch to nearly $\frac{1}{8}$t inch (·5 to 3 millimeters); but it has been pointed out by Warren that, on t and shoulders, it may be as thick as 5 or 6 mm.; and here it is almost formed of dense anastomosing bundles of connective tissue; sending down one hand fibrous prolongations through the subjacent panniculus adipos being penetrated obliquely on the other hand by columns of fat cells, extend from that layer to the bases of the small hair-follicles, and conduct vessels to these and to the surface of the skin.

Bundles of plain muscular tissue are distributed in the substa the corium wherever hairs occur; their connection with the will be afterwards explained. Muscular bundles of the same ki

Fig. 221.

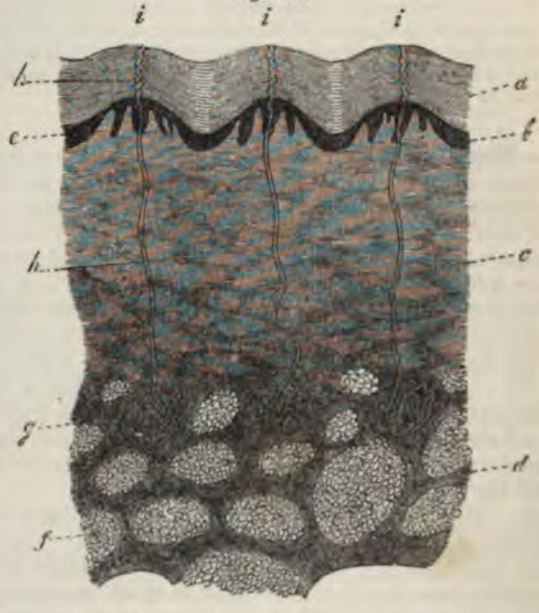


Fig. 221.—VERTICAL SECTION OF THE SKIN AND SUBCUTANEOUS TISSUE, FROM THE THE THUMB, ACROSS THE RIDGES AND FURROWS. MAGNIFIED 20 DIAMETERS (K

a, horny, and *b*, Malpighian layer of the epidermis; *c*, corium; *d*, *panniculus a* *e*, papillæ on the ridges; *f*, fat-clusters; *g*, sweat-glands; *h*, sweat-ducts; *i*, th ings on the surface.

found in the subcutaneous tissue of the scrotum, penis, perineu areola of the nipple, as well as in the nipple itself. They join t reticular layers, attached to the under surface of the corium. areola they are disposed circularly.

For convenience of description it is not unusual to speak

parts of the skin endowed with less tactile sensibility, the p
smaller, shorter, fewer in number, and irregularly scattered. (
they are reduced to from $\frac{1}{800}$ to $\frac{1}{500}$ of an inch ; and here th
disappear altogether, or are replaced by slightly elevated retic
Fine blood-vessels enter most of the papillæ, forming eit
capillary loops in each, or dividing into two or more capillar
according to the size of the papilla and its simple or comp
which turn round in the form of loops and return to the ve
papillæ receive nerves, to be presently noticed.

Blood-vessels and lymphatics.—The arteries divide i
cutaneous tissue, and, as their branches pass from this deep

Fig. 223.

Fig. 223.—MAGNIFIED VIEW OF FOUR OF TH
THE EPIDERMIS, WITH SHORT FURROWS
ACROSS THEM : ALSO THE OPENINGS OF THE
DUCTS (after Breschet).

towards the surface of the skin, t
offsets to the fat-clusters, sweat-g
hair-follicles. They divide and
again near the surface, and at length,
ing it, form a network of capillaries,
gonal meshes. Fine looped branches
the superficial arteries into the papillæ,
mentioned. The veins closely accor
arteries.

Lymphatics are found in all parts,
probably not everywhere in equal num
are abundant and large in some parts of the skin, as on th
and round the nipple. They form at least two networks, one
and another more deeply situated, which intercommunicate b
vessels, whilst the deeper net-work joins the lymphatics of the
neous tissue. According to Klein there is a continuous plexu
the whole thickness of the corium, and all the vessels possess va
most superficial network, although close to the surface of the
beneath the net of superficial blood-capillaries, which are muc
than the lymphatic capillaries. In certain parts on the palm
lymphatics pass into the papillæ, but do not reach their summit
lymphatics accompany the blood-vessels, two passing comm
each small artery and vein, and joining and anastomosing
vessels.

As in other kinds of connective tissue, the lymphatics of the skin
to originate in the cell-spaces of the tissue, and since the cells lie f
part in rows between the bundles, the combined spaces form interfasci
which can be injected with the lymphatics. The superficial cell-space
cate with the intercellular channels of the epithelium, and thus th
brought into connection with the lymphatics. The cell-spaces of
tissue can similarly be injected.

Nerves.—Nerves are supplied in very different proportions t
regions of the skin, and according to the degree of sensibili
pass upwards towards the papillary surface, where they form p
which the meshes become closer as they approach the surfac

terminates in front by the "free edge." A small portion c
near the root, named from its shape the *lunula*, is whiter tha
This appearance is due partly to some degree of opacity of the
of the nail at this point, and partly to the skin beneath bein
cular than in front.

The part of the corium to which the nail is attached, and
in fact it is secreted or generated, is named the *matrix*. This
the skin is highly vascular and thickly covered with larg
papillæ. Posteriorly the matrix forms a crescentic groove o
in the middle but getting shallower at the sides, which lodg
of the nail; the rest of the matrix, before the groove, is usu
the *bed* of the nail. The small lighter coloured part of the r
the groove and corresponding with the lunula of the nail,
with papillæ having no regular arrangement, but the whole
surface of the matrix situated in front of this, and supporting
of the nail, is marked with longitudinal and very slightly
ridges cleft at their summits into rows of papillæ. These
laminæ, as they are sometimes, and perhaps more suitably,

Fig. 225.

Fig. 225.—VERTICAL SECTION THROUGH A S
OF THE NAIL AND MA
MAGNIFIED (Kölliker).

A, corium of the na
into ridges or laminæ,
between corresponding
the nail; B, Malpighian,
layer; *d*, deepest and
e, upper more flattened
pighian layer.

into corresponding
the under surface o
The cuticle, advan
the dorsum of the
doubling back, be
tinuous with the n
posterior edge, th
round the margin of
in which the nail
in front the cuti
point of the finge
continuous with the under surface of the nail a little way
free edge.

The nail, like the cuticle, is made up of epithelial cells. Th
most superficial of these are the broadest and hardest, but a
time very thin, and so intimately connected together that th
tive limits are scarcely discernible. They form the exterior,
of the nail, and cohere together in irregular layers, so as to
part a lamellar structure. On the other hand, the youngest c
are those situated at the root and under surface, are softe
rounded or polygonal shape. The deepest layer differs some
the others, in having its cells elongated, and arranged perpe
as in the case of the epidermis. Thus the under part of th
225, B) corresponds in nature with the Malpighian or muco

mis, and the upper part (c) with the horny layer. As in the e epidermis, the hardened scales of the nails may be made to re- eir cellular character by treatment with caustic alkali, and after- h water; and then it is seen that they still retain their nuclei. owth of the nail is effected by a constant generation of cells at nd under surface. Each successive series of these cells being nd pushed from their original place by others, they become flat- o dry, hard, and inseparably coherent scales. By the addition lls at the posterior edge the nail is made to advance, and by ition of similar particles to its under surface it grows in thick- that it is thicker at the free border than at the root. The nail s merely a modified and exuberant part of the epidermis, the at one time raised, whether that membrane is continued under- loses its significance. When a nail is thrown off by suppura- pulled away by violence, a new one is produced in its place, any of the cells of the deeper layers of the epithelium are left.

ion and growth of the Nails.—In the third month of intra-uterine rt of the embryonic corium which becomes the matrix of the nail is by the commencing curvilinear groove, which limits it posteriorly and The epidermis on the matrix then begins to assume, in its under part, ters of a nail, which may, therefore, be said to be at first embedded in nic cuticle. The rudiment of the nail proper first appears at the art of the matrix, and grows forward from this over the bed (Unna). nd of the fifth month it becomes free at the anterior border, and in h month decidedly begins and thenceforth continues to grow in length. e free end is long and thin, being manifestly the earlier formed part been pushed forward. This breaks or is pared off after birth, and, as le nail continues to grow, its flattened cells, at first easily separable, rder and more coherent, as in after-life.

rage rate of growth of the nails is about $\frac{1}{33}$ of an inch per week. ound that the nails grow rather faster in summer than in winter, and e right hand than in the left. He also observed a difference in the nails fingers: thus the growth was fastest in the middle finger and slowest umb. A careful series of experiments by H. J. Benham, have con- rally the observations of Berthold, but no clear difference could be etween the two hands, and the growth appeared to be slowest in the t. In some individuals these differences were not observed.

HAIRS.

consists of the root, which is fixed in the skin, the stem, and the point. The **stem** is generally cylindrical, but re or less flattened: when the hair is entire, it becomes gra- aller towards the point. The length and thickness vary different individuals and races of mankind as well as in regions of the body. In the straight-haired races the indi- irs are coarser and thicker and the section more circular than olly-haired races, in which the section is smaller and oval, the g sometimes markedly flattened. The section is largest in American Indians, Chinese and especially in the Japanese. ured hair is usually finer than black.

m is covered with a coating of finely imbricated scales, the projecting edges of which give rise to a series of fine waved lines, which may be seen with the microscope on the surface ir (fig. 226, A). Within this scaly covering, by some called

the *hair-cuticle*, is a *fibrous substance* which in all cases ... the chief part and often the whole of the stem; but in ... the axis is occupied by a substance of a different nature, ... *medulla* or *pith*. The *fibrous substance* is translucent, ... longitudinal opaque streaks of darker colour intermixed. It ... broken up into straight, rigid, longitudinal fibres, which, ... rated, are found to be flattened, broad in the middle and ... at each end, with dark and rough edges. The fibres ... be resolved into flattened cells of a fusiform outline; these ... transparent, or marked with only a few dark specks. The ... of the fibrous substance is caused by oblong patches of pigment-... and generally diffused colouring matter of less intensity. Very ...

Fig. 226.

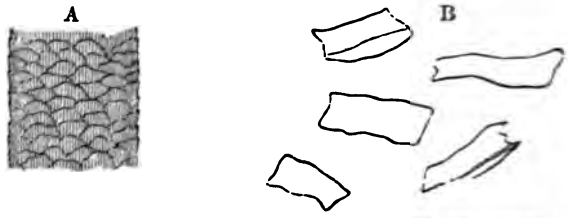


Fig. 226.—A, Surface of a white hair, magnified 160 diameters. The ... lines mark the upper or free edges of the cortical scales. B, ... scales, magnified 350 diameter (after Kölliker).

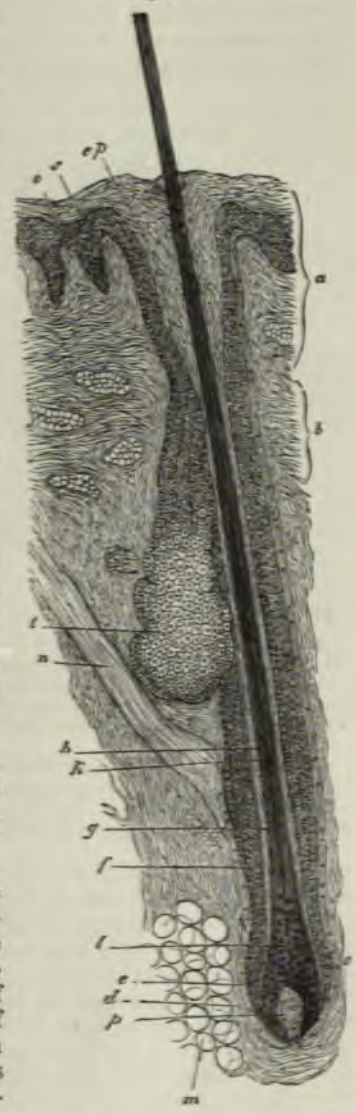
elongated nuclei are also discovered by means of reagents, whilst ... or marks of another description in the fibrous substance are occas... by minute irregularly shaped cavities containing air. These air-... nules are abundant in white hairs, and are best seen in them, ... being no risk of deception from pigment-specks; indeed they may ... altogether wanting in very dark hairs. Viewed by transmitted ... they are dark, but brilliantly white by reflected light. When a ... hair has been boiled in water, ether, or oil of turpentine, these cavi... become filled with fluid, and are then quite pellucid; but when a ... which has been thus treated is dried, the air quickly finds its way ... into the lacunæ, and they resume their original aspect.

The *medulla* or *pith*, as already remarked, does not exist in all ... It is wanting in the fine hairs over the general surface of the body, ... is not commonly met with in those of the head; nor in the hairs ... children under five years. When present it occupies the centre of ... shaft and ceases towards the point. When viewed by transmitted ... light, it is more opaque and deep-coloured than the fibrous part; ... reflected light, on the other hand, it is white, its colour being chiefly ... due to the contained air-particles. It is composed of rows of soft cells ... differing in shape, but generally angular, and containing minute ... particles, some resembling fine fat granules, intermixed with minute air-... bubbles. The whole forms a continuous dark mass along the middle of ... the stem, interrupted at parts for a greater or less extent. In the latter ... case, the axis of the stem at the interruptions is fibrous like the sur-... rounding parts.

The **root** of the hair is lighter in colour and softer than the stem; it swells out at its lower end into a bulbous enlargement or knob (fig.

c), and is received into a recess of the skin named the *hair-follicle*, *h*, when the hair is of considerable size, reaches down into the sub- neous fat.

Fig. 227.



27.—Hair-follicle, in longitudinal sec- s. Moderately magnified. (Biesiadecki.)

outh of the hair-follicle; *b*, its neck; *c*, r bulbous enlargement; *d*, *e*, dermic coat r and inner layers, the innermost or hyaline e is not shown); *f*, *g*, epidermic coat (outer inner root-sheath); *h*, fibrous substance of hair; *k*, medulla; *l*, hair-knob; *m*, fat in subcutaneous tissue; *n*, arrector pili; *o*, illa of the cutis; *p*, papilla of the hair-knob; Malpighian layer of the epidermis; *cp*, horny er, represented in the figure as continuous h the inner root-sheath, but this is somewhat btful; *t*, sebaceous gland.

The follicle, which receives near its outh the opening ducts of one or ore sebaceous glands (*t*), is some- hat dilated at the bottom, to corre- spond with the bulging of the root; it consists of an outer coat continuous with the corium, and an epidermic lining continuous with the cuticle.

The outer or *dermic coat* of the follicle is thin but firm, and consists of three layers. The most external (fig. 229, *a*) is formed of connective tissue in longi- tudinal bundles, without elastic fibres, but with numerous corpuscles. It is highly vascular, and provided with nerves. It is continuous above with the corium, and determines the form of the follicle. The most internal layer (*hyaline layer*, Kölliker) (fig. 229, *d*) is a transparent homogeneous mem- brane, marked transversely on its inner surface with some raised lines, and not reaching so high as the mouth of the follicle; it corresponds with the mem- brana propria or basement membrane of allied structures. Between the two is a layer extending from the bottom of the follicle as high as the entrance of the sebaceous glands, composed of an indistinctly fibrous matrix, which tears transversely, and of transversely dis- posed connective tissue corpuscles, with oblong nuclei (fig. 229, *c*). This layer is continuous with the so-called papillary part of the cutis vera, and its blood-vessels are continuous above with those of that layer.

The *epidermic coat* of the follicle adheres closely to the root of the

hair, and commonly separates, in great part, from the follicle and abides by the hair when the latter is pulled out; hence it is sometimes named the "root-sheath." It consists of an outer, softer, and more opaque stratum (fig. 229, *e*), next to the dermic coat of the follicle, and an internal more transparent layer (fig. 229, *f*, *g*) next to the hair. The former, named also the *outer root-sheath*, and by much the thicker of the two, corresponds with the Malpighian layer of the epidermis in general, and contains soft polygonal cells, including pigment-granules in the

Fig. 228.

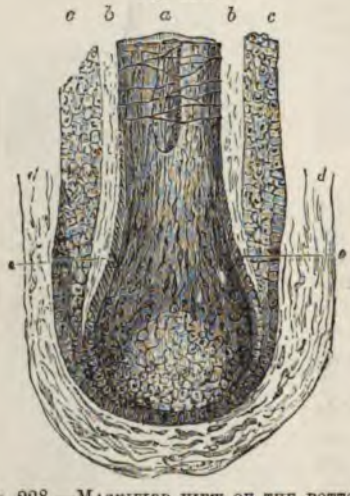


Fig. 229.

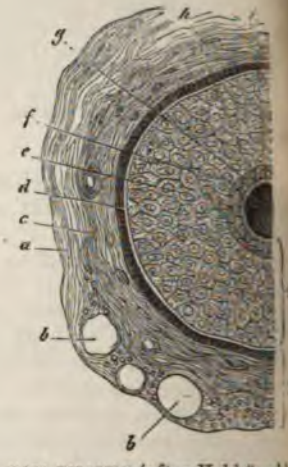


Fig. 228.—Magnified view of the bottom of a hair-follicle (after Kohlrausch).

a, hair showing medulla, fibrous substance, and cuticle; *b*, inner, and *c*, outer layer of the epidermic lining of the hair-follicle; *d*, dermic or external coat of the hair-follicle, shown in part; *e*, imbricated scales above forming a cortical layer on the surface of the hair. The adjacent cuticle of the root-sheath is not represented, and the papilla is only faintly indicated in the lower part of the knob.

Fig. 229.—Section of hair-follicle (Biesiadecki).

1, Dermic coat of follicle; 2, epidermic coat or root-sheath; *a*, outer layer of dermic coat, with blood-vessels, *b*, *b*, cut across; *c*, middle layer; *d*, inner or hyaline layer; *e*, outer root-sheath; *f*, *g*, inner root-sheath; *h*, cuticle of root-sheath; *i*, hair.

coloured races, which at the lower part form a much thinner stratum and pass continuously into those of the hair-knob; the internal layer or *inner root-sheath*, represents the superficial or horny layer of the epidermis, but is not continuous with that part of the skin, ceasing abruptly a little below the orifices of the sebaceous ducts. Lining the root-sheath internally is a layer of imbricated, downwardly projecting scales, the *cuticle of the root-sheath* (fig. 229, *h*), which is applied to the cuticle of the hair proper, to whose upwardly directed scales it fits like a mould. Its scales, as well as those of the hair-cuticle, pass, at the bottom of the follicle, into a layer of columnar cells which covers the surface of the hair-knob. The inner root-sheath itself consists of two layers, which towards the bottom of the follicle become blended into one. The innermost (that next the cuticula) is known as *Huxley's layer;* it consists of flattened polygonal nucleated cells, two or three deep. The outermost (*Henle's layer*) is composed of oblong, somewhat flattened cells without nuclei,

ween which gaps frequently occur, so as to give it the aspect of a per-ated membrane. At the lower part both layers pass into a single er of large polygonal nucleated cells without openings between them. the upper part also of the follicle the two layers of the inner root-eath are not distinguishable from one another (Ebner).

The soft, bulbous enlargement of the root of the hair is attached its base to the bottom of the follicle, and at the circumference of is attached part it is continuous with the epidermic lining (fig. 228). the bottom of the follicle it, in fact, takes the place of the epider-is, of which it is a growth or extension, and this part of the follicle the true matrix of the hair, being, in reality, a part of the corium

g. 230. SECTION OF THE SKIN OF THE HEAD, WITH TWO HAIR FOLLICLES, SLIGHTLY MAGNIFIED (Kölliker).

a, epidermis; *b*, corium; *c*, muscles of e hair-follicles.

Fig. 230.

hough sunk below the general sur-ce), which supplies material for e production of the hair. From e bottom of this follicle rises a all vascular papilla, usually of a ngi-form shape (fig. 227, *p*). The pilla fits into a corresponding excavation of the hair-knob. In the ge tactile hairs on the snout of the seal and some other animals it is ry conspicuous. As the follicle, in short, is a recess of the corium, so e hair-papilla is a cutaneous papilla rising up in the bottom of it. ervous branches enter the hair-follicles, but their final distribution is scure. Some filaments enter the papilla, and many fibres appear to ter the epithelium, where they probably end as in the Malpighian layer the epidermis. In the tactile hairs of animals, the nerves are scribed (Schöbl) as passing upwards over the outer root-sheath, there sing their white substance and forming a close plexus with vertical eshes; finally ending in an annular expansion, which encircles the hair st below the orifices of the sebaceous glands, and is in immediate con-ction with the hyaline layer of the follicle. In the larger tactile hairs e bulb is surrounded by cavernous tissue, which lies between the outer d middle layers of the dermic coat.

Muscles of the Hairs.—Slender bundles of plain muscular tissue rrectores pili) are connected with the hair-follicles (figs. 227, 230). hey arise, generally by a number of fasciculi, from the most superficial rt of the corium, and joining to form a somewhat flattened and plexi-rm muscle they pass down obliquely to be inserted into the outside of e follicle below the sebaceous glands, which they in a measure embrace their passage. In the dermic coat of the follicle some of the muscular bres become transverse and partly encircle the lower part of the follicle. hey are placed on the side to which the hair slopes, so that their tion in elevating the hair is evident.

Development of hair in the fœtus.—The rudiments of the hairs may be dis-rned at the end of the third or beginning of the fourth month of intra-uterine e, as little black specks beneath the cuticle. They are formed of down-owths of the Malpighian layer, which sink into the corium (fig. 231). A mogeneous limiting membrane next appears (*i*), inclosing the collection of

cells, and continuous above with a similar simple film which at this time [illegible] between the cuticle and the corium; it becomes the innermost or hyaline layer of the dermic coat of the follicle. The hair-rudiments next lengthen and swell [illegible] at the bottom, so as to assume a flask-shape. Outside the limitary membrane [illegible] fibres, corpuscles, and other constituents of the dermic coat of the follicle become formed. While this is going on outside, the cells within the follicle undergo change. Those in the middle lengthen out conformably with the axis of the follicle, and give rise to the appearance of a short conical miniature hair, faintly distinguishable

Fig. 231.

Fig. 231.—HAIR-RUDIMENT FROM AN EMBRYO OF SIX WEEKS, MAGNIFIED 350 DIAMETERS (Kölliker).

a, horny, and *b*, mucous or Malpighian layer of cuticle; *i*, limitary membrane; [illegible] cells (some of which are assuming an oblong figure) which chiefly form the future hair

by difference of shade from the surrounding mass of cells, which are also slightly elongated, but across the direction of the follicle. The papilla (fig. 232, *h*) grows up from the corium into the swollen root of the little hair; and the residuum of cells contained within the rudimentary follicle form the root-sheath, the inner

Fig. 232.

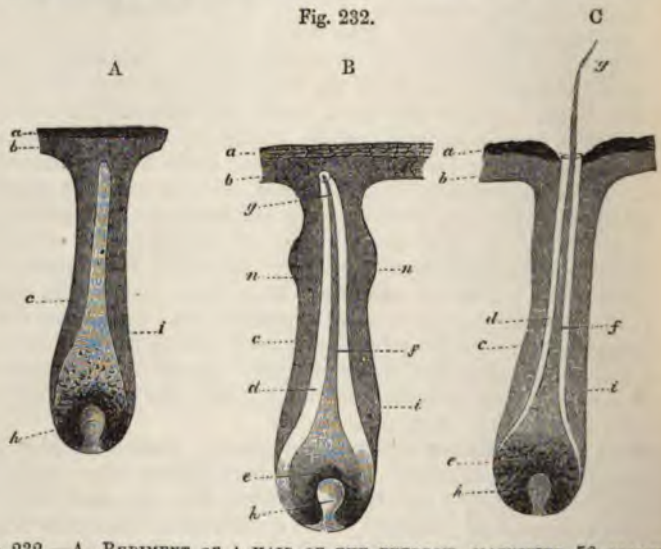


Fig. 232.—A. RUDIMENT OF A HAIR OF THE EYEBROW, MAGNIFIED 50 DIAMETERS (Kölliker).

The cells form an internal cone indicating the position of the future hair. *a*, horny layer of cuticle; *b*, mucous layer; *c*, external layer of root-sheath; *i*, limitary membrane; *h*, papilla.

B.—HAIR-RUDIMENT FROM THE EYEBROW, WITH THE YOUNG HAIR NOT YET RISEN THROUGH THE CUTICLE.

e, hair-knob; *f*, stem, and *g*, point of the hair; *d*, internal layer of the root-sheath still inclosing the hair; *n*, *n*, commencing sebaceous follicles.

C.—HAIR-FOLLICLE FROM THE EYEBROW WITH THE HAIR JUST PROTRUDED; THE INNER LAYER OF THE ROOT-SHEATH RISES TO THE MOUTH OF THE HAIR-FOLLICLE.

the old papilla, but is formed in a fresh hair-germ which buds out fro outer root-sheath, and in which a new papilla becomes developed; the old p and hair-bulb and the lower part of the primary follicle having first b gradually atrophied. When a hair is pulled out, a new one grows in its provided the follicle (from which the growth proceeds) remains entire.

Growth of hair.—On the surface of the papilla, at the bottom of the f there is a continual multiplication of cells. These for the most part lengt and unite into the flattened fibres which compose the fibrous part of th and certain of them getting filled with pigment, give rise to the coloured and patches in that tissue; their nuclei, at first, also lengthen in the same n but, at last, partly become indistinct. The cells next the circumference into the scales which form the imbricated cuticular layer. The medulla, w exists, is formed by the cells nearest the centre.

The substance of the hair, of epidermic nature, is, like the epidermis quite extravascular, but like that structure also, it is organised and sub internal organic changes. Thus, in the progress of its growth, the cells their figure, and acquire greater consistency. In consequence of their elon the hair, bulbous at the commencement, becomes reduced in diameter, an drical above. But it cannot be said to what precise distance from t organic changes may extend. Some have imagined that the hairs are permeated by a fluid from the root to the point, but this has not been The sudden change of the colour of the hair from dark to grey, whic times happens, has never been satisfactorily explained: it appears gene be due to the development of air between the elongated cells composing th

The rate of growth of hair is about half-an-inch per month.

Distribution and arrangement.—Hairs are found on all parts of th except the palms of the hands and soles of the feet, the dorsal surfac third phalanges of the fingers and toes, the glans, and the inner surface prepuce. On the scalp they are set in groups, on the rest of the skin most part singly. Except those of the eyelashes, which are implanted dicularly to the surface, they have usually a slanting direction, which stant in the same parts. In the negro the hair follicles have been fou curved, so that the papilla may look in a direction parallel to or even aw the surface of the skin (Stewart).

With the exception of the bones and teeth, no tissue of the body wit decay after death so long as the hair, and hence it is often found pres sepulchres, when nothing else remains but the skeleton.

GLANDS OF THE SKIN.

The sudoriferous glands or sweat-glands (figs. 221 and 2 These are seated on the under surface of the corium, and at v depths in the subcutaneous adipose tissue. They have the app of small round reddish bodies, each of which, when examined w microscope, is found to consist of a fine tube, coiled up into (though sometimes forming an irregular or flattened figure); fron the tube is continued, as the duct of the gland, upwards thro true skin and cuticle, and opens on the surface by a slightly v orifice. The duct, as it passes through the epidermis, is twiste corkscrew, that is, in parts where the epidermis is sufficiently t give room for this; lower down it is straight or but slightly Sometimes the duct is formed of two coiled-up branches which j short distance from the gland, as in fig. 234. The tube, both in th and where it forms the excretory duct, has an investment of co tissue, continuous with the corium, and reaching no higher t surface of the true skin, and within this consists of a thin me propria and an epithelial lining, consisting in the gland of a sing

ubical or columnar cells (often containing brownish pigment) and, in duct, of two or more layers bounded next the lumen by a fine cuticular ng. The epithelium of the duct is continuous with the epidermis, which ne forms the twisted part of the duct. The tube is larger in the proper reting portion of the gland than in the duct, and in the former,

Fig. 234.

. 234.—Magnified view of a sweat-gland, with its duct (Wagner).

, the gland surrounded by fat-cells; *b*, the duct passing through corium; *c*, its continuation through the lower, and *d*, through upper part of the epidermis.

tween the epithelium and the basement membrane, a layer of plain muscular fibres longitudinally sposed. These are absent in the duct, which is elf often coiled two or three times before leaving e gland, but its coils are distinguished from those the gland proper by the differences just mentioned. he secreting cells of the sweat-glands show the culiar rod-like structure characteristic of many and-cells, and minute canals are said to pass from e lumen of the tube between the opposed surfaces the cells (Ranvier). In the large glands in the illa, at the root of the penis, on the labia majora, d in the neighbourhood of the anus, the layer of n-striated muscular fibre-cells between the epithe- um and basement membrane is very well marked. In the larger ands, also, the duct is rarely simple, being more usually parted by peated dichotomous division into several branches, which before ending ve off short cæcal processes; in rare cases the branches anastomose. carefully detaching the cuticle from the true skin, after its connection

Fig. 235.

. 235. — Section of a sweat-land. Highly magnified Biesiadecki).

he tubules are seen variously cut. basement-membrane; *b*, lining s; *c*, lumen of tube; *d*, blood- els and uniting connective tissue.

been loosened by putrefac- n, it usually happens that cuticular linings of the eat-ducts get separated m their interior to a certain pth, and are drawn out in form of short threads attached to the under rface of the epidermis. The coils of the gland-tube are loosely held ether by connective tissue (fig. 235), which may form a sort of cap- e round the body of the gland. Each little sweat-gland is supplied h a dense cluster of capillary blood-vessels.

Distribution.—Sweat-glands exist most numerously in regions unprovided h hairs, but they occur in all parts of the skin, and may in some cases

open into hair-follicles. According to Krause, nearly 2800 open on a square inch of the palm of the hand, and somewhat fewer on an equal extent of the sole of the foot. He assigns rather more than half this number to a square inch on the back of the hand, and not quite so many to an equal portion of surface on the forehead, and the front and sides of the neck. On the breast, abdomen, and fore-arm, he reckons about 1100 to the inch, while on the lower limbs and the back part of the neck and trunk, the number in the same space is not more than from 400 to 600.

The **size** of the sweat-glands also varies. According to the observer last named, their average diameter is about $\frac{1}{70}$ of an inch; but in some parts they are larger than this—as, for example, in the groin, but especially in the axilla. In this last situation Krause found the greater number to measure from $\frac{1}{56}$ to $\frac{1}{12}$ of an inch, and some nearly $\frac{1}{6}$ of an inch in diameter.

The **development** of the sweat-glands has been carefully studied by Kölliker. Their rudiments, when first discoverable in the embryo, have much the same

Fig. 237.

Fig. 236.

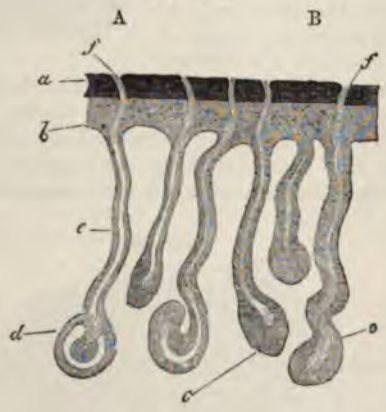


Fig. 236.—Developing sweat glands from a seven months fœtus. Magnified 350 diameters (Kölliker).

a, horny layer of the epidermis; *b*, Malpighian layer; *d*, rudimentary gland; *e*, lumen of the duct, opening at *f* upon the surface of the skin.

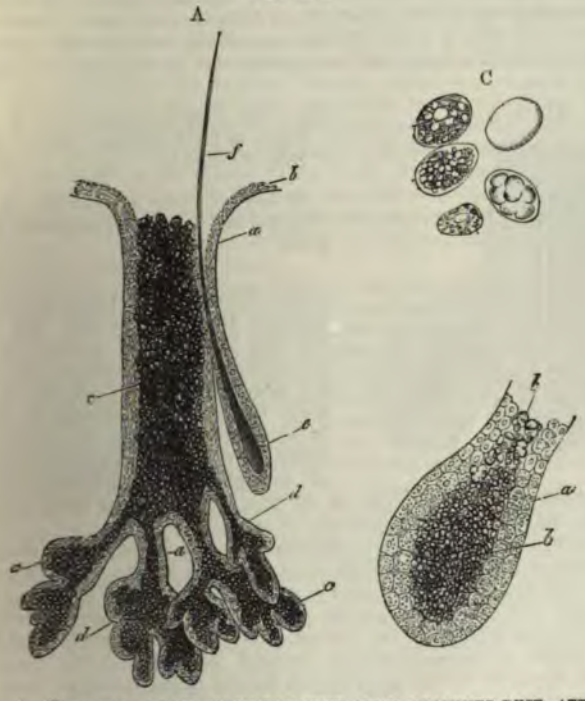
Fig. 237.—Ceruminous glands in the skin of the external auditory meatus. Magnified 20 diameters (Kölliker).

a, cutis vera; *b*, Malpighian layer, *c*, horny layer of the epidermis; *d*, glandular coil; *e*, duct; *f*, its opening; *g*, hair follicle; *h*, sebaceous gland; *i*, fat.

ce as those of the hairs, and, in like manner, consist of processes of the layer of the epidermis, which pass down and are received into corre- recesses of the corium (fig. 236). They are formed throughout of cells into a solid mass of a club shape, continuous by its small end with ighian layer of the cuticle, and elsewhere surrounded by a homoge- niting membrane, which is prolonged above between the corium and The subsequent changes consist in the elongation of the rudimentary e formation of a cavity along its axis—at first without an outlet—the tion of its canal through the epidermis to open on the surface, and, in the e, the coiling up of the gradually lengthening gland-tube into a compact the twisting of the excretory duct as it proceeds to the orifice. The scular tissue of the sweat-glands is said to be developed from some of the m-cells of the rudimentary gland (Ranvier). If this be so, it is the only stance, in the higher animals, of muscular tissue being developed from erm.

ruminous glands in the auditory passage consist of a tube coiled into a the sweat-glands (fig. 237): and there is such a further correspondence the two, in structure and mode of development, that the ceruminous ay be regarded as a mere variety of the sudoriferous.

Fig. 238.



8.—A, Sebaceous gland from the nose with branched duct, attached to a small hair-follicle. Magnified 50 diameters (from Kölliker).

thelium continuous with *b*, the Malpighian layer of the epidermis; *c*, contents of *d*, *d*, the groups of saccules on the branches of the duct; *e*, hair-follicle; *f*, hair.

Terminal saccule of a sebaceous gland. Magnified 250 diameters.

ithelium lining the saccule; *b*, sebaceous matter, partly still within the cells.

arated cells from the interior of an alveolus, containing fatty particles of varying degrees of fineness (from Kölliker).

The **sebaceous glands** (figs. 227, 238, A) pour out their secretion at the roots of the hairs, for, with very few exceptions, they open into the hair-follicles, and are found wherever there are hairs. Each has a short duct which opens at a little distance within the mouth of the hair-follicle, and by its other end, leads to a cluster of small rounded secreting saccules which as well as the duct are lined by epithelium (fig. 238, B), and usually charged with the fatty secretion, mixed with detached epithelium-particles. The number of saccular recesses connected with the duct usually varies from four or five to twenty; it may be reduced to two or three, in very small glands, or even to one, but this is rare. These glands are lodged in the substance of the corium. Several may open into the same hair-follicle, surrounding it on all sides, and their size is not regulated by the magnitude of the hair. Thus, some of the largest are connected with the fine downy hairs on the alæ of the nose and other parts of the face, and there they often become unduly charged with pent-up secretion.

Development of the sebaceous glands.—The rudiments of the sebaceous glands sprout like little buds from the sides of the hair-follicles; they are at first, in fact, excrescences of the external layer of the root-sheath (fig. 239), and are composed entirely of similar cells. Each little process soon assumes a flask-shape and in due time a group of cells containing fat particles appears in its centre, and gradually extends itself along the axis of the pedicle until it pene-

Fig. 239.

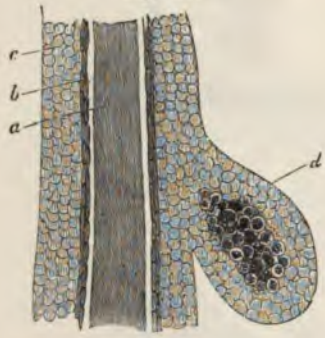


Fig. 239.—DEVELOPMENT OF A SEBACEOUS GLAND IN A SIX MONTHS' FŒTUS. 250 DIAMETERS (Kölliker).

a, hair; *b*, inner root-sheath; *c*, outer root-sheath of hair-follicle; *d*, rudiment of sebaceous gland.

trates through the root-sheath, and the fat-cells thus escape into the cavity of the hair-follicle, and constitute the first secretion of the sebaceous gland. They are soon succeeded by others of the same kind, and the little gland is established in its office. Additional saccules and recesses, by which the originally simple cavity of the gland is complicated, are formed by budding out of its epithelium, as the first was produced from the epithelial root-sheath, and are excavated in a similar manner.

It would thus appear that the rudiments of the hair-follicles, sweat-glands, and sebaceous glands, are all derived from the same source. They all originally appear as solid bud-like excrescences of the soft Malpighian or mucous layer of the epidermis, (for the outer stratum of the root-sheath must be regarded as such); these grow down into the corium, in which recesses are formed to receive them, and which, of course, yields the material required both for the production of new cells, for their further growth, and for the maintenance of their secreting function.

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ADDENDA.

few additional remarks may here be made concerning some of the subjects ted of in the preceding part on General Anatomy, chiefly on account of itional light having been thrown on them by researches which have been lished since the previous sheets were printed.

he structure and mode of division of the cell-nucleus.* It has been wn that in addition to the evident network within the nucleus which was viously described (p. 9, fig. 8), there frequently exists a far finer interlace- nt of exquisitely delicate fibrils of nucleoplasm which occupy the meshes of coarse network, and except with the best immersion objectives, either remain een, or their nodal points appear in the form of fine granules (as in fig. 10, p. 12). It was the staining of this finest network which led to the notion that nuclear matrix itself in the resting cell is slightly stained by hæmatoxylin or anin (see p. 9), and therefore contains "chromatic" substance in solution; bably however this is not the case.†

marked difference between the active and the resting nucleus consists in the that in the former the nucleoplasmic fibres, at any one stage of division, are niform size, while in the resting condition they show great irregularities, being me parts comparatively coarse and in others immeasurably fine. This differ- is still further accentuated by the accumulation of the nucleoplasm in the ng nucleus at one or more of the nodes of the network into irregular or rounded ps, the latter being the nucleoli. In a nucleus which is about to undergo ion and in new nuclei which have just been formed by division (fig 10, *q*) only are the nucleoplasmic filaments uniform but there are no nodal clumps ucleoli; so that the presence of the last named bodies may be said to be acteristic of a resting condition of the nucleus. Indeed in the completely tive condition it may happen that the nucleoplasm becomes wholly col- d to form nuclear membrane and nucleolus, so that the network is either no er present or has become so highly attenuated as to be no longer discernible.

he longitudinal cleavage of the V-shaped fibres in the aster-phase (p. 13 and 10, *g*, *h*) is said by Retzius to occur constantly, so that in this way the ber of those filaments is doubled. It is not improbable that the two fibres lting from the cleavage pass into different daughter-nuclei, but it has not possible to trace this with sufficient clearness.

he very widely diffused occurrence of the phenomena of karyokinesis (it has been observed in almost every description of active cell in the animal body)

Klein, Atlas of Histology; *Fleming*, Beiträge, &c., No. III, in Arch. f. mikr. Anat., 1881; *Pfitzner*, Beobachtungen, &c., in the same Journal; *Retzius*, Biologische rsuch., Stockholm, 1881.

† According to Klein these fibrils of the nucleus are directly continuous with the proto- nic intracellular reticulum; but this is doubted by other observers, who describe the us as being sharply bounded from the surrounding protoplasm.

has led most observers to the conclusion that it is an essential preliminary to cell-division. Some however, still believe that in some cases, simple constriction of the nucleus into two, or its budding into several, may suffice to produce division, it being thought that the time occupied in the complex process of karyokinesis is too long to permit of the active cell-multiplication which is known to occur in certain cases. As a fact, however, the time occupied is not so long as might be supposed:—in cold-blooded animals it has been found to take from

Fig. 240.

Fig. 240.—A CILIATED EPITHELIUM-CELL OF A MOLLUSK (Engelmann).

one and a half to five hours; in cells from a carcinoma in man only half an hour (Fleming); and in cells of the intervertebral cartilage of the cat, examined in warm salt solution, the process of karyokinesis was on one occasion observed by me to proceed to the stage of the formation of the daughter-nuclei (amphi-astral stage) in a few minutes (E. A. S.).

Lastly, Fleming has conclusively shown that in the dividing nucleus of the plant-cell and in that of the animal ovum (see p. 14), the chromatic substance is also in the form of filaments, although these are so small that they can only be made out by the most improved objectives.

Ciliated Epithelium.—It has been shown by Engelmann* that in large ciliated cells such as those which line the alimentary canal of some mollusks, e. g. the mussel and oyster, it is possible to make out that the highly refracting free border of the cell to which the cilia are attached is in reality formed of a number of small juxtaposed fusiform or cylindrical bodies (*basal pieces*). To each of these a cilium is attached on the one side, and from the other end there passes towards the end of the cell a fine, varicose filament; these filaments are termed by Engelmann the *rootlets* of the cilia. They approach one another as they traverse the length of the cell, and may be united towards the extremity into a single thread. They are not connected with the nucleus. The cilia are attached to the basal pieces of the cell, each one by a somewhat narrow, soft portion or neck (*intermediate segment* of Engelmann). It is here that the cilia usually break off from the cell (see fig. 240). Beyond the neck the cilium swells out into a small bulbous enlargement, and from this the shaft tapers gradually to its extremity. The rootlets, as well as the cilia themselves, are said by Engelmann to be double refracting, whereas the basal piece is isotropous. A similar structure, although less distinct, is also to be made out in ciliated cells from the higher animals (frog and rabbit).

Striated muscular fibre.—There is good reason to believe from its chemical reactions that the sarcolemma is of the nature of connective tissue, and not a cell-membrane as has generally been thought.† The intimate nature of its union with the tendon-bundle (see fig. 127, p. 130) would seem to point to the same conclusion.

The ending of sensory nerves.—Many of the nerve-fibres of those parts of the skin which are especially endowed with tactile sensibility, penetrate into the epithelium and terminate after branching a number of times, in expansions of the axis-cylinder (*tactile menisci*) which are applied to certain cells of the deeper layers of the epidermis. These cells are apparently those described as tactile cells by Merkel (see p. 137), but according to Ranvier ‡ there is no actual connection of the nerve-fibre with the cell.

* Pflüger's Archiv. XXIII., 1880.

† *Froriep*, in the Arch. f. Anat., 1878. See also on the subject of striated muscle a paper by *Merkel* (in the Arch. f. mikr. Anat., XIX., 1881), who somewhat modifies the view he had before taken (see p. 128), and another by *Retzius* (Biol. Unters., 1881), who describes the appearances of the muscle of Dytiscus much in the same manner as was done by me (Phil. Trans., 1873), but gives a different interpretation of them (E.A.S.).

‡ Nouvelles recherches s. l. corp. du tact, Comptes rendus, 1880; and Traité technique, sixième fascicule, 1882.

SPLANCHNOLOGY.

THE CEREBRO-SPINAL AXIS.

The *cerebro-spinal axis* is divided by anatomists into the *brain* or *phalon*, the enlarged upper mass placed within the cranium, and the *al cord* contained within the vertebral canal. It is symmetrical in form and structure throughout, consisting of a right and a left half, rated to a certain extent by longitudinal fissures, but united by ious portions of white and grey nervous substance which cross from side to the other, and form the *commissures* of the brain and spinal d.

The cerebro-spinal axis is surrounded within the skull and vertebral al by three connective tissue membranes, between which are spaces upied by a clear fluid similar in its general nature to lymph (cerebro-al fluid). These envelopes, which will be described hereafter, are, , a firm fibrous membrane named the dura mater, which is placed most erficially; 2nd, a delicate membrane called the arachnoid; and, 3rd, highly vascular membrane named the pia mater, which is next to, closely invests the surface of the brain and cord.

SPINAL CORD.

The **spinal cord**, or **spinal marrow** (medulla spinalis), is that part he cerebro-spinal axis which is situated within the vertebral canal. s about 18 inches (45 centim.) long, and extends from the margin of foramen magnum of the occipital bone to about the lower part of body of the first lumbar vertebra. Above, it is continued into the ulla oblongata; below, it tapers conically and ends in a slender ment, the *filum terminale* or *central ligament* of the spinal cord.

Though the cord usually ends near the lower border of the body of the first bar vertebra, its termination is sometimes a little above or below that point, as site to the last dorsal or to the second lumbar vertebra. The position of the r end of the cord also varies according to the state of curvature of the verte-column, in the flexion forwards of which the end of the cord is slightly d. In the fœtus, at an early period, the embryonic cord occupies the whole th of the vertebral canal; but, after the third month, the canal and the of the lumbar and sacral nerves begin to grow more rapidly than the cord , so that at birth the lower end reaches only to the third lumbar vertebra.

he cord is enclosed in the vertebral canal within a sheath (theca, 241, 244) considerably longer and larger than itself, formed by the mater, and separated from the walls of the canal by venous plexuses,

and much loose areolar tissue. The cavity of the theca between the pia mater and the dura mater is occupied by cerebro-spinal fluid, and is divided by the curtain-like arachnoid into the two spaces, subdural and subarachnoid, above mentioned. Within the latter the cord, covered

Fig. 241.

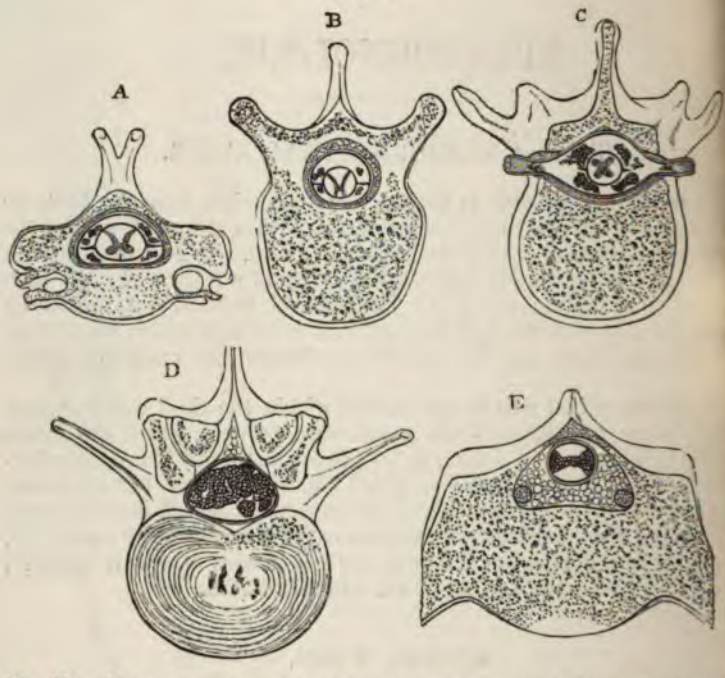


Fig. 241.—SECTIONS SHOWING THE GENERAL RELATIONS OF THE SPINAL CORD TO THE INCLOSING THECA, AND OF THIS TO THE VERTEBRAL CANAL (Key and Retzius).

A, through the fifth cervical vertebra; B, through the tenth dorsal vertebra; C, through the first lumbar vertebra and the foramen of exit of the twelfth dorsal nerve-roots; D, through the disk between the second and third lumbar vertebræ; E, through the first sacral vertebra. In A, B, and C, the cord, covered by pia mater, is seen in the centre, with the ligamentum denticulatum attached to it on either side; the nerve-roots on either side form small groups which, since they pass obliquely downwards to their foramina of exit, are cut across; the dura matral sheath is separated by a considerable space from the cord, and by a quantity of loose areolar and fatty tissue from the wall of the vertebral canal. This tissue is in smaller amount in C. D and E are below the termination of the cord, and show sections of the nerve-bundles of the cauda equina within the theca, which is very large in D, but comparatively small in E, the vertebral canal in the latter being largely occupied by adipose tissue. In this are seen the sections of two large veins. The arachnoid is not represented in any of these sections.

closely by pia mater, is suspended, being kept in position by a ligament on each side (ligamentum denticulatum), which fixes it at frequent intervals to its sheath, and by the roots of the spinal nerves which pass across the space from the surface of the cord towards the intervertebral foramina.

The uppermost nerve-roots cross the space nearly horizontally

A), but the rest below one or two pass across more and more oblique d inclination until their is almost vertical (fig. and indeed the lower the theca below the on of the cord (fig. E), is occupied by the ig roots of the lumbar al nerves, passing to the between the correspond- ora. The mass of nerve- ich conceals the delicate minale, is named the *ina* (fig. 244 C).

Fig. 242.

VIEW OF THE CEREBRO-SPINAL (after Bourgery). ⅛

t half of the cranium and e body has been removed by section; the membranes of the of the brain and spinal cord cleared away, and the roots art of the fifth and ninth ves, and of all the spinal e right side, have been dis- and laid separately on the akull and on the several posite to the place of their it from the cranio-spinal

erebrum; C, cerebellum; P, ; *m o*, medulla oblongata; oint to the upper and lower of the spinal marrow; *c c*, umbar vertebral spine, marks quina; V, the three principal the nervus trigeminus; C I, pital or first cervical nerve; eighth or lowest cervical the first dorsal nerve; D XII, rsal; L I, the first lumbar the last lumbar; S I. the nerve; S V, the fifth; Co I, al nerve; *s*, the left sacral

ation between the bodies and e vertebræ and the places of of the nerve-roots to the illustrated by this figure. etailed information on this eader may consult Gowers osis of Diseases of the Spinal k.

Fig. 243.

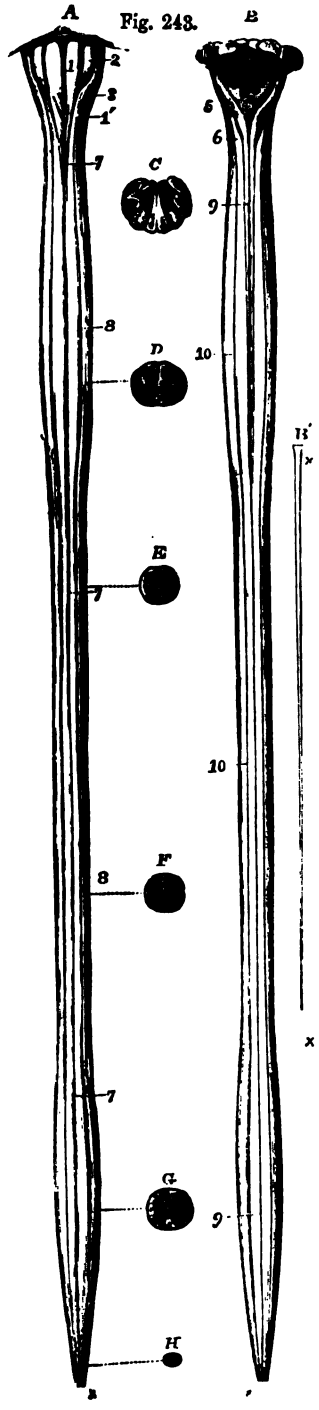


Fig. 243.—ANTERIOR AND POSTERIOR THE MEDULLA OBLONGATA AND SI WITH SECTIONS (Allen Thomson).

The cord has been divested of its and of the roots of the nerves. A is B a posterior view. In these figures prolongation, represented separately been removed; C shows a transv through the middle of the medulla D, a section through the middle of enlargement of the cord; E, throug dorsal region; F, through the lower; the middle of the lumbar enlargeme near the lower end of the conus medu

1 to 6 refer to parts of the medull the remaining numbers to parts of cord.

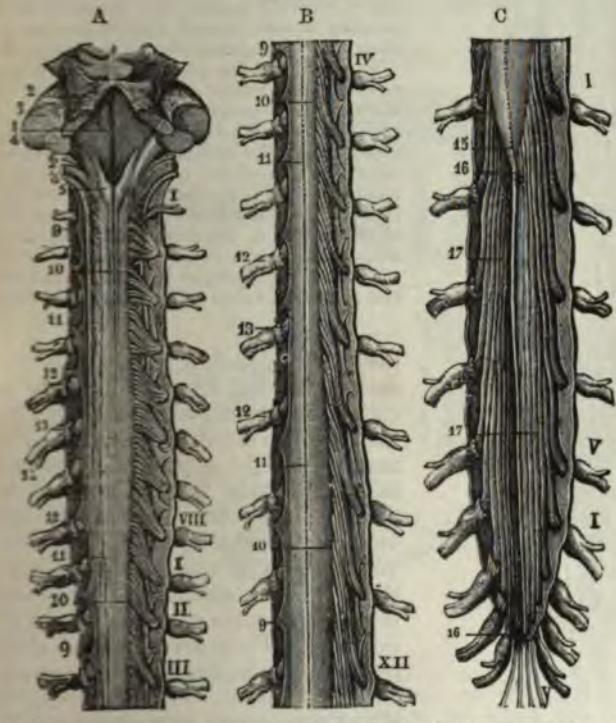
1, pyramids; 1', their decussation bodies; 3, lateral columns; 4, poste of the medulla oblongata; 4', calam rius; 5, funiculus gracilis; 6, poste columns passing to the side; 7, median fissure of the spinal cord; 8 lateral impression corresponding to ments of the anterior nerve roots; rior median fissure; 10, 10, po groove; ×, tapering extremity of ×, ×, in B', filum terminale.

In section the cord is r cular, especially in the dors but it is somewhat flatter and behind. In the dorsal measures about ten millim side to side, and about e before back. The cord is ever, of uniform diameter th but is swollen out in the ce lower dorsal regions, two en being thereby produced—an cervical, and a lower or lu 243). Of these the cervica ment is of greater size a than the lumbar. It ext the upper limit of the co first or second dorsal verte largest opposite the fifth cervical vertebra, where it from 13 to 14 mm. from si The lower or lumbar en begins at the tenth dorsal is largest opposite the twe (11—13 mm. across), and point becomes gradually sm antero-posterior diameter is n equal to the transverse than in the cervical enlargemen

mbar enlargement the cord tapers in the form of a cone (*conus Harris*), from the apex of which the small filiform prolongation is nued downwards.

cervical and lumbar enlargements have an evident relation to the large f the nerves which supply the upper and lower limbs, and which are con- d with those regions of the cord. At the commencement of its development embryo, the spinal cord is destitute of these enlargements, which, in their first rance and subsequent progress, correspond with the growth of the limbs.

Fig. 244.



244.—Posterior view of the medulla oblongata and of the spinal cord with its coverings and the roots of the nerves (Sappey). ½

theca or dura-matral sheath has been opened by a median incision along the whole , and is stretched out to each side. On the left side, in the upper and middle parts d B), the posterior roots of the nerves have been removed so as to expose the liga- um denticulatum, 9, and the anterior roots, 13; and along the right side the pos- roots, 10, are shown arising from the postero-lateral groove, and passing out through ra mater. The roman numbers indicate the different nerves in the cervical, dorsal, r, and sacral regions respectively; 11, posterior median fissure; 12, ganglia on nterior roots; 14, the united nerve beyond the ganglion; 15, tapering lower end spinal cord; 16, filum terminale; 17, cauda equina.

e **terminal filament** (filum terminale, central ligament) (fig. *b*, *b*) descends in the middle line amongst the nerves composing the equina, and, becoming blended with the lower end of the sheath ite to the first or second sacral vertebra, perforates the dura mater,

and receiving an investment from it, passes on to be attached wi
to the periosteum of the lower end of the sacral canal, or to the

Fig. 245.

Fig. 245.—POSTERIOR VIEW OF THE LOWER
THE SPINAL CORD WITH THE CAUDA EQU
SHEATH (Allen Thomson). ½

The sheath has been opened from behind and
towards the sides; on the left side all the ro
nerves are entire; on the right side both ro
first and second lumbar nerves are entire,
rest have been divided close to the place of
sage through the sheath. The bones of the
sketched in their natural relative position to
place of the filum terminale and the lowest ne
a, placed on the posterior median fissu
middle of the lumbar enlargement of the co
the terminal filament, drawn slightly aside
at its middle, and descending within the du
sheath; *b'*, *b'*, its prolongation beyond the s
upon the back of the coccygeal bones; *c*,
matral sheath; *d*, double foramina in this for
rate passage of the anterior and posterior roo
of the nerves; *e*, ligamentum denticulatum;
DXII, the tenth and twelfth dorsal nerves; L
the first and fifth lumbar nerves; SI, and SV
and fifth sacral nerves; CI, the coccygeal nerv

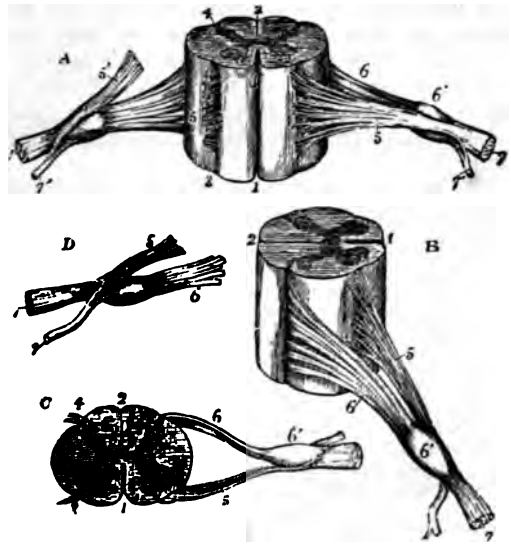
the coccyx. It is a prolongation of
mater, enclosing for about half its le
enlarged continuation of the central
the cord (see below, p. 268), with a lit
matter near the upper end. Below
mination of the canal, the filum is
composed of connective tissue, with
vessels prolonged from the anterio
vessels, and on either side there ru
three or four small bundles of me
nerve-fibres, some of which have a fe
lion-cells. These nerve-bundles are r
by Rauber as representing rudimentar
geal nerve-roots. They have no co
with the coccygeal nerves proper.

The filum terminale is distingui
its silvery hue from the nerves amon
it lies.

Fissures.—The spinal cord is
pletely divided into a right and a
by two fissures which pass in from th
of the anterior and posterior surfa
penetrate through the greater part
thickness. Of these two *median fiss*
anterior (fig. 246, 1) is wider and t
more distinct than the posterior, alt
does not, in most parts, penetrate to more than one-third the t
of the cord, while the posterior fissure may reach more than
from back to front. The anterior contains a fold of the pia ma

many blood-vessels, which are thus conducted to the centre of the
At the bottom of this fissure is a transverse connecting portion
te substance named the *anterior* or *white commissure.*
posterior (fig. 246, 2) is not an actual fissure, for, although the
halves of the posterior part of the cord are quite separate, there
distinct fold of the pia mater between them, but merely a septum
nective tissue and blood-vessels prolonged from that membrane
passes in nearly to the centre of the cord. Its position is marked,
lly in the lumbar enlargement and in the cervical region, by a
cial furrow. At its end is the *posterior* or *grey commissure.*
ides these two median fissures, a lateral furrow is seen on each

Fig. 246.



246. — DIFFERENT
S OF A PORTION OF
SPINAL CORD FROM
CERVICAL REGION
THE ROOTS OF
NERVES. Slightly
ged (Allen Thom-

the anterior sur-
the specimen is
the anterior nerve-
f the right side
been divided; in
ew of the right side
n; in C, the upper
is shown; in D,
rve-roots and gan-
are shown from
1, the anterior
n fissure; 2, pos-
median fissure; 3,
-lateral impression,
hich the bundles of
terior nerve-root are
to spread (this im-
on is too distinct
figure); 4, postero-
l groove into which
bundles of the pos-
r root are seen to sink; 5, anterior root; 5', in A, the anterior root divided and
d upwards; 6, the posterior root, the fibres of which pass into the ganglion, 6';
e united or compound nerve; 7', the posterior primary branch, seen in A and D to
rived in part from the anterior and in part from the posterior root.

of the cord, corresponding with the line of attachment of the pos-
r roots of the spinal nerves. It is named the *postero-lateral groove*
246, C, 4). Each lateral half of the cord is divided superficially by
postero-lateral groove into a posterior and an antero-lateral part.
attachment of the anterior roots, however, subdivides the latter into
rior and lateral portions.

antero-lateral groove is often described in the line of origin of the ante-
roots of the nerves, but has no real existence. The fibres of these roots
ct, unlike the posterior, do not dip into the spinal cord in one narrow line,
pread over a space of some breadth.

the posterior surface of the cord, at least in the upper part, there

are two slightly marked longitudinal furrows (fig. 243, 9, 9) situated on each side, about one millimeter from the posterior median and marking off, in the cervical region, a slender tract (the median column). These are better marked in some individuals than others.

INTERNAL STRUCTURE OF THE SPINAL CORD: RELATIVE PROPORTION OF GREY AND WHITE MATTER.

Grey matter.—When the spinal cord is cut across (figs. 247, 248) it is seen that the grey matter occupies the more central part, and is almost completely enclosed by the white matter. The grey matter appears in the form of two irregularly crescentic portions on each side, united across the middle line by the posterior grey commissure before mentioned, so that its section may be compared in shape to the letter H. The concave side of each lateral crescent faces outwards, and in consequence of the depth of the posterior median fissure the commissure of grey matter joins the crescents nearer their anterior than their posterior ends, except in the lumbar region of the cord.

The two horns or cornua of each crescent are named from their position anterior and posterior: the *anterior cornu* (fig. 247, *a. c*) is

Fig. 247.

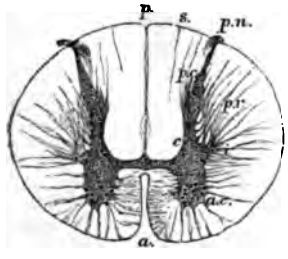


Fig. 247.—Section of the spinal cord in the upper part of the dorsal region (E. A. S.). ½

a, anterior median fissure; *p*, posterior median fissure; *p. n*, posterior nerve-roots entering the postero-lateral groove; *a. c*, anterior cornu of grey matter; *p. c*, posterior cornu; *i*, intermedio-lateral tract (lateral cornu); *p. r*, processus reticularis; *c*, posterior vesicular column of Clarke; *s*, pia-matral septum forming the lateral boundary of the posterior median column.

shorter and broader, and is everywhere separated from the surface of the cord by white matter which is traversed by the bundles of the anterior roots at the part where these enter the cord. The *posterior cornu* (*p. c*) is longer and narrower, and tapers almost to a point (*apex cornu posterioris*), which closely approaches the external surface of the cord at the postero-lateral sulcus, with which it is connected by fibres of the posterior roots (*p. n*), and between these by processes of the superficial neuroglia. The posterior cornu is slightly narrowed at its base (*cervix cornu*); from that place it gradually expands into the main part of the cornu (*caput cornu*), and from this it tapers in the way just noticed. Near its tip the caput cornu has a peculiar semi-transparent aspect, whence it was named *substantia gelatinosa* by Rolando.

Near the middle of the outer surface of each crescent the grey matter is less sharply marked off than elsewhere from the white matter; portions of grey matter extending into the lateral white column and uniting with one another into what in sections appears like a network enclosing portions of white substance (*p. r*). This is known as the *processus reticularis*; it is best marked in the cervical region (fig. 248, C5). At

large and broad. The posterior cornua are narrow in the dorsal, but very broad in the lumbar region. The grey s in a series of sections to be most abundant in the lumb the cord, and least in the dorsal.

It is clear that what appear in section as irregular crescentic matter are in reality long irregularly fluted columns, and that th band uniting the convex edge of the crescents is a flattened expa ing the columns along their whole length. But it is both custo venient to speak of the various parts of the grey matter of the co their appearance in sections, although the term "columns" is applied to what appear in section as groups of nerve-cells, occupi parts of the grey matter, as well as to the several portions of t immediately to be described.

Fig. 249. Fig. 249.—Section of lower extremity of spin about six times.

The peculiar form of the lower extremity of seen.

Central canal.—Extending through the whole le cord, in the substance of the grey commissure, there is a 247) which, in sections of the cord, is barely visible, a the naked eye. It is continued above into the medulla ob it gradually approaches the posterior surface and eventually the calamus scriptorius of the fourth ventricle. At the lo cord, near the extremity of the conus medullaris, it becomes shaped like the letter T, and is stated by some observers t posterior surface of the cord ; but this is denied by others. canal, though minute, is an object of considerable interest part of the structure of the cord, it being the permanent re ectodermal canal from which the spinal cord is developed. distinctly seen in the lower vertebrata than in mammals.

White matter.—The white substance of each half of t pletely encloses the grey matter except opposite the pos This last therefore serves to separate off a smaller *posterior* which is somewhat wedge-shaped in section and is bound by the posterior median fissure, from the rest of the whi which forms a large *antero-lateral white column* (figs. 246 t antero-lateral column is sometimes arbitrarily divided i and lateral white columns, the place of passage of the b anterior nerve-roots being taken as the limit between the tw these are scattered over a considerable part of the transve is clear that the limit cannot be distinctly fixed.

The white substance is traversed by imperfect septa c tissue prolonged inwards from the pia mater. Most of these and somewhat variable in position, with the exception o cervical region extending inwards towards the grey com the sulcus before described as bounding the posterior me This septum (fig. 247, *s*) cuts off a small portion of the post next to the posterior median fissure, corresponding to the the posterior median column on the outside.

The lateral symmetry of the spinal cord is not always p white columns especially are sometimes found slightly to va

generally caused by the fact that the amount of the pyramidal white matter differs somewhat on the two sides of the cord (see 278).

ite matter of the cord, especially that of the lateral column, gradually in amount from below upwards, receiving a con- accession opposite the roots of the larger nerves which supply This more sudden increase in the amount of white matter is ed in the anterior and posterior columns. These relations are shown in the appended curves (fig. 250) which have been

Fig. 250.

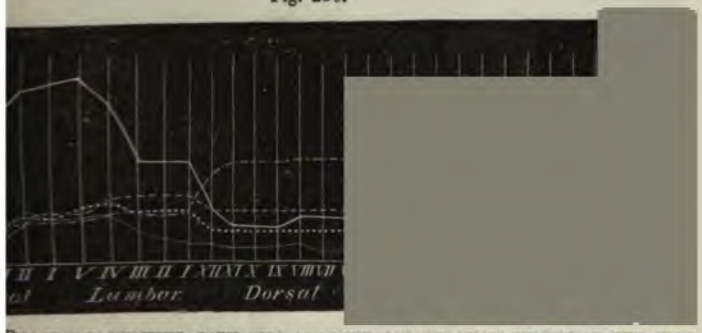


DIAGRAM SHOWING BOTH THE ABSOLUTE AND RELATIVE EXTENT OF THE GREY ND OF THE WHITE COLUMNS IN SUCCESSIVE SECTIONAL AREAS OF THE SPINAL WELL AS THE SECTIONAL AREAS OF THE SEVERAL ENTERING NERVE-ROOTS from Ludwig and Woroschiloff). (E. A. S.)

onal areas of the several entering nerve-roots (*n.r*) as well as the extent of matter (*gr*), and of the lateral, posterior, and anterior columns of white *c.*, *p. c.*, and *a. c.*), are represented in superposed curves, the common which (*abs.*) is intersected at equal intervals by as many ordinates as there spinal nerves. In the ordinates each millimeter above the abscissa represents quare centimeter of sectional area.

ed by Ludwig and Woroschiloff from measurements by Stilling. unt of the grey matter in the different regions is also given, as he sectional areas of the roots of the spinal nerves. It is seen osite to the origins of the large nerves there is a marked increase nount of grey matter.

nterior or white commissure is likewise proportional in size to ring nerve-roots.

MICROSCOPIC STRUCTURE OF THE SPINAL CORD.

white substance of the spinal cord is almost wholly composed of inally coursing medullated nerve-fibres, which in stained trans- tions of the cord (fig. 251) appear as clear rings with a stained section of the axis-cylinder—either in the middle of the ring or omewhat to one side. The fibres vary much in size, and in many the section larger and smaller fibres are intermixed, but some characterized by containing many large fibres, others for the rt small fibres. The largest fibres are in the posterior part of al column, the smallest in the part of the lateral column in the rhood of the processus reticularis, but the fibres of the

posterior median column are also very small. The white column imperfectly divided into secondary columns by incomplete septa fibrillar connective tissue which are prolonged inwards from the layer of the pia mater, and convey bloodvessels to the interior of cord.

Fig. 251.

Fig. 251.—A SMALL PORTION OF A TRANSVERSE SECTION OF THE HUMAN SPINAL CORD HIGHLY MAGNIFIED. (E. A. S.)

a, *a*, superficial neuroglia; *b*, *b*, transverse section of part of the lateral column of the cord in which the dark points are the axis-cylinders, and the clear areas the medullary substance of the nerve-fibres: the superficial neuroglia is seen to exhibit the appearance of a fine network in which numerous nuclei and one or two *corpora amylacea* (*c*, *c*) are embedded, and to extend inwards among the nerve-fibres.

Immediately beneath the pia mater and closely investing the cord externally is a layer of what in the fresh condition appears a homogeneous or finely granular substance with nuclei embedded in it here and there. In sections of the cord hardened in alcohol or chromic acid, the substance in question is finely reticulated (fig. 251, *a*, *a*). The layer which it forms is very thin over some parts of the surface but comparatively thick in others, and where the pia-matral septa pass into the cord, it accompanies and invests them and their ramifications in the white substance, passing with them between the irregular bundles of nerve-fibres. Not only does this subpial reticular substance accompany the prolongations of the fibrillar tissue and largely assist in forming the incomplete septa above mentioned, but it extends independently amongst the individual nerve-fibres, occupying the interstices between them, and serving as a uniting medium in which they are embedded. Hence it was named by Virchow the *neuroglia*. The nuclei in it belong for the most part to small cells (neuroglia-cells) which occur in considerable numbers in some parts of the tissue; but others to more conspicuous cells, known as the cells of Deiters, which are stellate in section and are found here and there in the larger interstices between the nerve-fibres. Along the line of origin of the posterior roots the superficial neuroglia is prolonged into the cornu of grey matter, and expands in it to form the substantia gelatinosa of Rolando. This, as before mentioned, presents a transparent jelly-like appearance in the fresh condition, but in sections of the hardened cord it is finely reticular,

ing numerous neuroglia-cells, and a few bloodvessels. Some of dles of nerve-fibres of the posterior root traverse this substance, contains, especially near the cornu proper and the posterior column, a few small scattered nerve-cells; but on the whole are fewer true nervous elements in it than in any other part of rd.

he constitution of the rest of the cornua the neuroglia takes part r less extent than in the substantia gelatinosa. It is true that it nged both from this and from the white substance into the grey and pervades the latter throughout in every part. But it is obscured in this situation by the proper nervous elements, which grey substance are of three kinds. In the first place are found lar nerve-cells, mostly of large size, scattered singly or occurring ps throughout the grey substance. Secondly, in connection with nd especially accumulated around the cells and cell-groups, is an ement of the finest nerve-fibrils, which is derived according to h from the ramification of the nerve-cells, and may be the medium munication between the several cells of a group or even between e cells and groups. Thirdly, occupying a considerable portion of y matter, are nerve-fibres, mostly of the medullated kind, and the finder processes of the nerve-cells; these traverse the grey matter rent directions, coursing for the most part in bundles which inter- rith one another, and confer on the grey matter a spongy appear- Hence it is sometimes known as the *substantia spongiosa*.

neuroglia is generally assumed to be a modified form of connective tissue. and Ewald find, however, that the tissue composing the substantia nea of Rolando (and probably the neuroglia-tissue generally) is similar in al nature to the network described by them in the medullated sheath of ves, and named "neuro-keratin" from its apparent nature and the resist- hich it offers to the action of digestive fluids (see p. 144). But this resisting appears to be conferred upon the tissue by the action of alcohol, for in the ate it is quite soft, and easily dissolved by the fluids in question. So that ument in favour of its ectodermal origin which is sometimes drawn from posed chemical constitution of the substance, is not sufficiently strong to re the view, originally taught by Kölliker, that the neuroglia (or *reticulum* rmed it) is a peculiar form of connective tissue (allied to retiform tissue) l, together with the connective tissue septa which it accompanies, by rth from the mesoderm surrounding the embryonic central nervous system. esence of the neuroglia-cells in it, which resemble in general appearance connective tissue cells, is in favour of Kölliker's view.

ll concentrically striated globules, termed *corpora amylacea*, are very fre- y met with in the neuroglia of the cord, as well as in many of the parts of ntral nervous axis. They appear to be composed of proteid substance but, gh long recognized, their mode of formation and their meaning are still y unknown.

rangement of the nerve-cells in the grey matter. In trans- sections of the cord it is seen that the nerve-cells are not by any s equally distributed throughout the grey substance, but are arranged finite groups, which occupy the same relative position in successive ns. The groups are therefore the sections of longitudinal tracts of natter rich in nerve-cells, and named the *ganglionic*, or *vesicular* ns of the grey matter. The longitudinal continuity of the groups e seen in sections of the cord made parallel with its long axis and ig through the part of the grey matter where the groups occur.

Of these groups or columnar tracts of nerve-cells, the a most constant and contains the largest cells is found along t the anterior part of the anterior cornu where the nerve-cell the entering fibres of the anterior roots. There seems to be that many of these anterior or motor nerve-fibres are directly with the axis-cylinder processes of some of the nerve-cells o

Fig. 252.

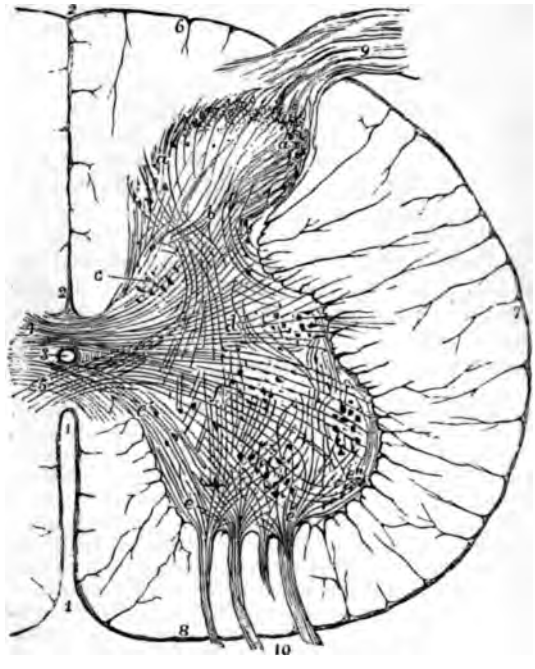


Fig. 252. SECTION SPINAL LUMBAR (Allen T

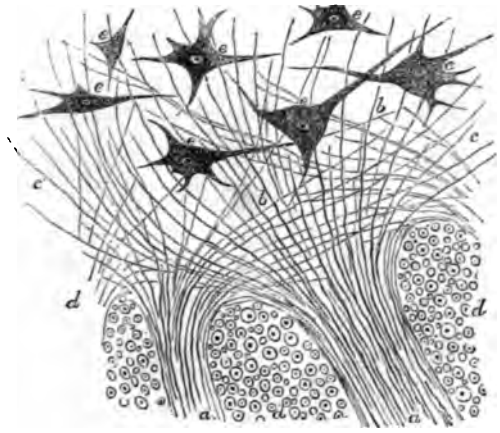
This is matic repre from a founded i statements Clarke and 1, anter sure; 2, p fissure; 3 lined with posterior c anterior c posterior c teral colum column; 9 posterior n ing in one of which posterior co into the pos 10, fascicu roots; a, posterioris nous substa b, the cervix terior vesic Clarke; to the group intermedio-

e, *e*, fibres of the anterior roots, entering the anterior cornu, and passing t the cells; *e'*, fibres from the anterior roots which decussate in the anterio *e''*, external fibres from the roots running round the outside of the ante towards the lateral columns; *f*, fibres from the posterior commissure and terior cornu running towards the anterior. Three groups of cells are seen cornu in this region of the cord; and from their position may be describe internal, and posterior.

Hence it is sometimes named the *motor ganglionic column*, bu generally known as the *ganglionic or vesicular column of the an* Its cells are in some parts collected into two groups, a la the lateral column of white matter, and a mesial nearer t column; in the lumbar enlargement there is a third, more de posterior group (fig. 252). Some of the cells which are anterior commissure send their axis-cylinder processes thro the other half of the cord: it is believed that these proce connected with nerve-fibres of the corresponding anterior other side.

ne of the lower vertebrates it may be made out that there are variations
ne of this column of cells in successive portions of the cord, the cells being
merous opposite the points of entrance of the nerve-roots, the at-
t of which to the cord is in them more localized than in man and
rtebrates. In this way somewhat of a segmental formation of the column
ted, and in some fishes and reptiles the enlargement of the group of cells
nclosing grey matter is sufficiently marked to produce an external swell-
site each nerve-pair.

Fig. 253.



—A SMALL POR-
F A TRANSVERSE
OF THE SPINAL
AT THE PLACE
TWO BUNDLES OF
RES OF THE AN-
ROOTS PASS INTO
REY SUBSTANCE.
Thomson.) $\frac{1}{350}$

wo bundles of
he anterior root
rough the white
of the cord, *d*,
fibres running
through the
stance towards
rior cornua; *c*,
spreading in the
rnua, on the one
rds the anterior
re, and on the
d the outer side
anterior cornu;
multipolar cells in the grey substance of the anterior cornu; the communication
hese cells and some of the nerve-fibres of the roots is not shown in the figure.

ond very well marked group or column of cells, which occupies
verse section an area at the inner or mesial angle of the base of
erior cornu (fig. 252, *c*), and appears cut off from the rest of the
tter by a curved bundle of fibres derived from the posterior root,
along the middle region of the cord from the third lumbar to the
cervical nerve. This was termed by Lockhart Clarke the *posterior*
r column; it is often known as *Clarke's column*. It is largest
ower part of the dorsal region. From the fact that it is almost
confined to that region of the cord it was termed by Stilling the
ucleus. But although ceasing above and below the points men-
it is not altogether unrepresented in other parts, for groups of
e found in a similar situation opposite the origin of the second
d sacral nerves (sacral nucleus of Stilling) and opposite the origin
hird and fourth cervical nerves (cervical nucleus); and elsewhere
e scattered cells in the same part of the section of the cord. The
this column are of moderate size, and their axis-cylinder pro-
end for the most part towards the lateral column. It is note-
that Clarke's column is best developed in the region of the cord
he column of the anterior cornu is least so.

ird column of cells lies in the intermedio-lateral tract (*column of*
mediolateral tract, fig. 252, *d*). Like that tract, the ganglionic
it contains only appears as a distinct formation in the dorsal
in other parts it blends more or less with the column of the

anterior cornu. Its cells, although large, are on the whole smaller t... those of the anterior cornu. In the upper part of the cervical re... group of cells becomes distinct in a similar situation, and is tra... by the roots of the spinal accessory nerve.

The above are the chief groups or columns of cells which are dis... guishable in transverse section, and of them the column of the ... cornu is the only one which can be described as extending alon... whole length of the cord. But in addition to the groups, a co... number of scattered cells are met with, distributed through the po...

Fig. 254.

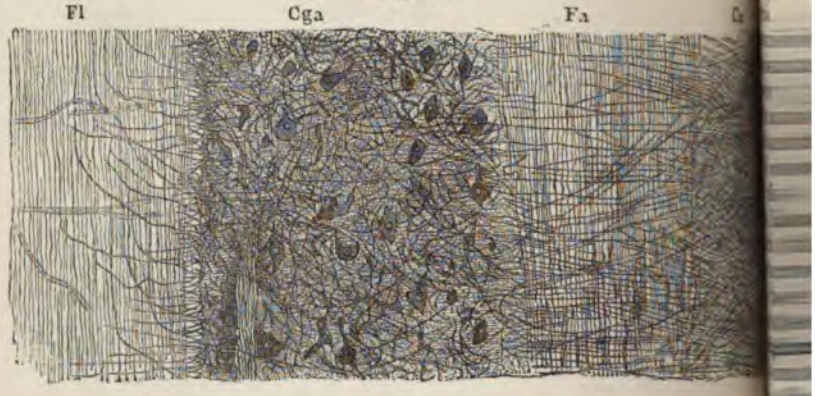


Fig. 254.—LONGITUDINAL SECTION OF THE CORD THROUGH THE ANTERIOR WHITE COMMISSURE AND ANTERIOR GREY CORNU. DORSAL REGION. (Henle). $\frac{4}{1}$

Only the left half of the section is represented.

Ca, anterior commissure with fibres passing into it through the anterior column from the grey matter, and decussating with those of the other side; *Fa*, anterior white column; *Cga*, anterior cornu of the grey matter; many of the multipolar cells are extended in a longitudinal direction; *Fl*, lateral column, into which fibres are seen passing from the grey cornu and turning upwards in a longitudinal direction.

cornu, and extending into the substantia gelatinosa of Rolando. These cells vary much in form and size, but are for the most part spindle-shaped and smaller than those previously mentioned. It is not known whether they have any special relation to the fibres of the posterior roots, although in the lamprey it has been shown by Freud that cells which appear to correspond with them send their axis-cylinders into those roots.

Commissures.—The *anterior commissure* (fig. 254, *Ca*) consists of medullated nerve-fibres which pass on each side, some into the anterior white column, others into the anterior horn of grey matter. Their course is not strictly transverse, many fibres which enter the anterior part of the commissure at one side leave it at the posterior portion on the other side. There is thus a double decussation at the middle line (fig. 252, 5). This decussation is most distinctly seen in the comparatively short and wide commissure of the lumbar region, and in the upper part of the cervical region. In the latter situation it appears as a continuation of the decussation of the anterior pyramids of the medulla oblongata, to be afterwards described. In addition to the transverse there are a few longitudinal bundles of fibres. The transverse fibres of the anterior commissure

[illegible] somewhat displaced by vessels which pass into the grey sub- [illegible] from the anterior fissure.

[illegible] *posterior commissure* is also composed of medullated fibres running [illegible] versely or with a slight obliquity, but there is a considerable amount [illegible] neuroglia between them, and this gives the grey aspect to the com- [illegible] re. In this commissure is contained the central canal of the spinal [illegible], the fibres of the commissure sweeping round it, leaving an [illegible] outside the epithelium of the canal almost free from nerve- [illegible], and occupied only by what appears like a portion of neuroglia, [illegible] ng in the hardened condition a reticulated structure and in the fresh [illegible] a gelatinous aspect. It is sometimes termed *substantia gelatinosa [illegible]ralis*. The outermost part is marked off from the rest by the more [illegible] centric disposition of its fibrils. There is rather more of the posterior [illegible] missure behind the central canal than in front. The fibres of the [illegible] terior part curve backwards on reaching the lateral crescents of grey [illegible] tter and pass towards the bundles of the posterior roots, whereas those [illegible] he anterior part diverge at various angles into the cervix cornu.

The *central canal* is lined with a layer of columnar ciliated epithelium. [illegible] e cells are slightly longer on the dorsal than on the ventral aspect of the [illegible] nal. Each cell is provided with a bunch of cilia on the side which is turned [illegible] wards the lumen of the canal: the other end of the cell is prolonged [illegible] to the reticular substance just mentioned, and there becomes lost to view. [illegible] In the adult the lumen of the central canal is not unfrequently [illegible] bliterated, being filled up by detached cells.

Origin of the spinal nerves.—The anterior and posterior roots of [illegible] e spinal nerves are attached along the sides of the cord, oppo- [illegible] te to the corresponding cornua of the grey matter; the posterior roots [illegible] a a straight line at the postero-lateral groove, and the anterior roots [illegible] cattered somewhat irregularly upon the surface (fig. 246, B).

The anterior roots are seen in a transverse section to pass through [illegible] white substance and to enter the grey cornu in several bundles, which [illegible] have a slight upward inclination, so as to be often cut obliquely if the [illegible] section be exactly in a transverse plane. Some of the fibres on reaching [illegible] the grey matter are directly connected with the axis-cylinder processes [illegible] of the large nerve-cells of the cornu. The others, and perhaps the [illegible] larger number, pass by the cells without, so far as can be seen, entering [illegible] into relation with them.

As soon as the bundles enter the grey matter, their fibres diverge [illegible] from one another, some going inwards towards the anterior commissure, [illegible] others outwards towards the anterior part of the lateral column and others [illegible] straight backwards to the posterior cornu (fig. 255). Of those which pass [illegible] inwards some are continued into the axis-cylinder processes of the mesial [illegible] group of cells of the anterior cornu, and others are stated to go to the [illegible] other side of the cord through the anterior commissure and perhaps to [illegible] become connected with the corresponding cells there. The outwardly [illegible] directed fibres of the root are partly connected with the lateral group of [illegible] anterior cornu cells, and partly enter the lateral white column and turn [illegible] upwards in it. The middle set of fibres again are partly connected to the [illegible] cells of the lateral group of the anterior cornu, and partly, as just men- [illegible] tioned, pass on to the posterior cornu without coming into relation with [illegible] the motor nerve-cells. Their further course here has not been traced. [illegible] According to Gerlach they are continued into some of the scattered cells [illegible] of the posterior cornu.

The posterior roots at their entrance into the cord are seen to
two sets. Of these the external and somewhat smaller ent
grey matter at once, passing in separate bundles, partly t
the substantia gelatinosa of Rolando, partly curving round t
stance. Their course, like that of the bundles of the anterior
is directed slightly obliquely upwards. In the substantia ge
many of the bundles become longitudinal, turning either up

Fig. 255.

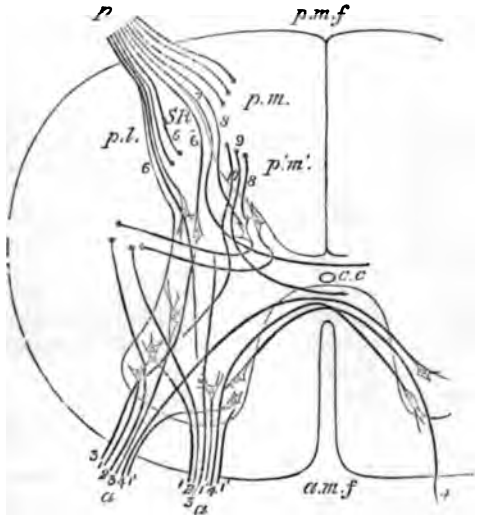


Fig. 255.—DIAGRAM
LUSTRATE THE
TAKEN BY THE
THE NERVE-ROOTS
ING THE SPINAL
(E.A.S.)

a, *a*, two funiculi
anterior root of a nerv
some of their fibres
into the lateral cells
anterior cornu; 1', 1',
passing into the mesial
the same cornu; 2, 2,
passing to the lateral
of the same side
joining nerve-cells;
fibres passing towards
terior cornu; 4, 4,
passing across the
commissure, to enter
cells in the anterior
the other side; *p*,
of the posterior root;
fibres of its lateral or
division coming through
around the gelatinous
stance of Rolando; some of these, 5, are represented as becoming longitudinal in
latter; others, 6, 6, as passing towards the anterior cornu, either directly or after
ing cells in the posterior cornu, and others, 7, as curving inwards towards the grey
missure; *p*, *m*, fibres of the mesial or inner division, entering the posterior colum
then becoming longitudinal; *p'*, *m'*, fibres from a posterior root which had joined
cord lower down and entered the posterior column, now passing into the grey matter
the root of the posterior cornu. Of these, 8, is represented as entering Clarke's colu
9, as curving around this and coursing to the anterior commissure, and 10, as p
towards the anterior cornu. The axis-cylinder processes of the cells of Clarke's colu
are shown arching round, and taking the direction of the lateral column.

a.m.f., anterior median fissure; *p.m.f.*, posterior median fissure; *c.c.*, central canal;
s.R., substantia gelatinosa of Rolando.

downwards for a certain distance, and then in all probability passing in
again horizontally. The rest pass at once horizontally into the grey
matter where for the most part they become lost, but some can be traced
as far as the anterior cornu, and others tend towards the posterior com-
missure, and probably pass through it to the other side.

The inner or principal bundle of the posterior root enters the posterior
white column. The fibres turn upwards in this and run longitudinally
for some distance. At length, after passing through several segments
of the cord, they turn in obliquely into the base of the posterior cornu,
which in their longitudinal course they have been gradually approaching.
(It is uncertain whether all the fibres thus turn in again or whether some
are continued along the column towards the encephalon.) Here they
form a well-marked bundle, which traverses the grey matter obliquely,

towards the anterior cornu, and cutting off in their passage a area of the grey substance in which, in the dorsal region, the Clarke's column lie. Some of the fibres of the bundle enter this nd there become longitudinal, others go towards the outer or group of cells of the anterior cornu, and others again bend y round towards the anterior commissure.

rse of the nerve-fibres in the spinal cord.—It is impossible ravel the tracts of nerve-fibres in their passage along the spinal and it is exceedingly difficult to trace the same fibre or fibres for istance in microscopical sections of the organ. But the task of ving out the course of certain sets of fibres has been much ated of late years by the application to the subject of certain al developmental and pathological methods of observation. Thus found that if the development of the spinal cord is carefully rved, the medullary substance of the nerve-fibres is formed later certain tracts of the white columns than in the rest of the white er, so that in transverse sections of the cord these tracts are easily nguishable by their more transparent grey appearance (Flechsig).

nother method by which similar results are arrived at consists in ng the course which the degeneration of the fibres pursues in con-nce of a lesion either in the encephalon, or in the spinal cord itself, en in the peripheral nerves; the lesions being produced by accidental ry, by pathological changes, or experimentally in animals (Schiefferer). The degenerations which follow are either the result of the lerian law that separation of a nerve-fibre from the nerve-cell with h it is connected as its trophic (nutritive) centre is followed by de-rative changes in the part of the fibre thus separated from that centre, ey may follow from the prolonged disuse of a nervous tract, especially ung animals, as when a limb is removed altogether or a nerve or nerves nanently paralyzed. The degeneration which follows a lesion of part he nervous centre, and especially section of the spinal cord, is in some s centrifugal, in others centripetal. The place of the degenerated rous substance is taken by connective tissue and this, by its difference ehaviour to staining fluids, can easily be distinguished by the sur-ding undegenerated white substance. In some cases groups of nerve-are affected by the degenerative processes, and some of the cells may eventually disappear altogether. When this is the case it may be med that they are in some way in connection with the tracts of s which have simultaneously undergone degeneration.

the **antero-lateral column** there are at least two such tracts which by these methods be traced not only along the greater part of the al cord but into or from certain parts of the encephalon. The two s in question have accordingly been named, from their upper con-ons, the *pyramidal tract* or *tracts*, and the *direct lateral cerebellar tract.* he *pyramidal tract* is directly traceable down from the anterior pyramid he medulla oblongata. The greater number of the fibres which pose the pyramid, cross at the upper limit of the spinal cord, down h they pass in the posterior part of the lateral column as a compact lle of fibres occupying in transverse section a somewhat oval area h lies in the angle between the posterior cornu and the outer surface e cord, but is in most parts separated from both by bundles of fibres nging to other systems. This *lateral* or *crossed part of the pyramidal* (fig. 256, *c.p.l.*) can be traced as far as the third or fourth pair of

sacral nerves, becoming gradually smaller below and appr surface of the cord.

Some of the fibres of the pyramids of the medulla do not the upper limit of the cord. These pass down close to t median fissure, forming the *anterior* or *uncrossed portion midal tract* (*d.p.t.*), which gradually diminishes as it is traced and ceases altogether at about the middle or end of the do the cord. It is highly probable that the decussation of t pyramidal tracts goes on along their whole course, their fi

Fig. 256.

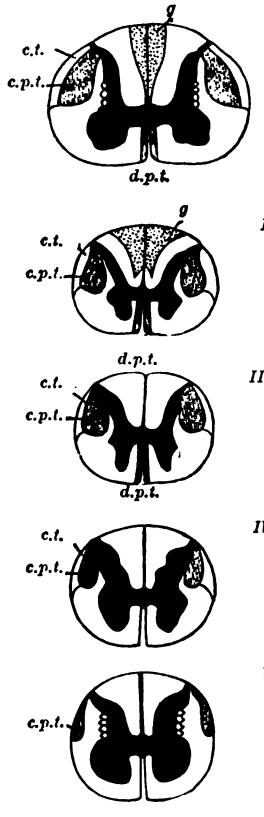


Fig. 256.—DIAGRAMMATIC SECTIONS CORD AT DIFFERENT PARTS TO SH LOCALIZED TRACTS OF FIBRES IN T STANCE (after Flechsig). ONE AN THE NATURAL SIZE.

I., at the level of the sixth cervica the third dorsal; *III.*, of the sixth the twelfth dorsal; *V.*, at the leve lumbar.

d.p.t., direct or anterior pyramida crossed or lateral pyramidal tract cerebellar tract; *g*, tract of Goll.

through the anterior comm through the grey matter of t side to reach the lateral pyr on the other side of the cord. sating fibres in the anterior would thus form a continua larger decussation in the me gata.

There is much variation in the of the anterior pyramidal tracts individuals. In some they are s as to form a visible prominence of the cord close to the anterior r in others they are quite small, or altogether. In this case it ma that the decussation of the pyra known to be subject to consider has been more complete than us cases again the anterior pyramid be unsymmetrical, being more dev side than on the other, or the tra may be wholly undeveloped.

The *direct lateral cerebellar tract* (*c.t.*) lies between the later tract and the outer surface of the cord, occupying a some area of the transverse section, which in the upper regions reaches to the tip of the posterior cornu, but lower down b limited, and is separated from the cornu by the interve adjoining pyramidal tract. It disappears at about the sec lumbar nerves.

It is found that there are a few fibres scattered throug bouring parts of the lateral column which, from their

THE ENCEPHALON.

The encephalon comprises the medulla oblongata, the cerel
the pons Varolii, the mesencephalon, the thalamencephalo
cerebral hemispheres; the three parts last named being t
lectively the cerebrum. The *medulla oblongata* (fig. 257, D)
continuous with the spinal cord: it is the lowest part of the
and rests against the basilar process of the occipital bone.
bellum (B) occupies the posterior fossa of the cranium. Its
forms the posterior boundary of a space, which is bounded

Fig. 257.

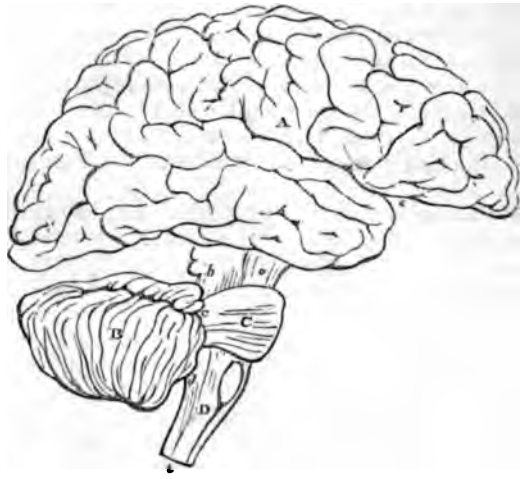


Fig. 257.—
LINE OF
LOW, AS
RIGHT SI

The part
sented as
one anoth
more than
to show thei
A, cerebrum
Sylvius; B,
C, pons Va
dulla oblon
duncles of t
b, *c*, *d*, sup
and inferior
the cerebellu
marked *a*,
isthmus ence

the poster
of the m
longata, s
is named
ventricle of the brain. On each side of this, the cerebellum is
by peduncles below with the medulla oblongata, above with the
and in the middle with the *pons Varolii* (C), a commissure
two halves of the cerebellum. The *cerebrum* (A) includes
maining and by far the largest part of the encephalon. It
with the parts below by a comparatively narrow and constrict
or *isthmus* (*a*, *b*), part of which, forming the crura cerebr
through the pons Varolii into the medulla oblongata, whilst ar
on each side joins the cerebellum. The cerebrum is mainly
of the large convoluted cerebral hemispheres, and within it ar
and two lateral ventricles. It occupies the vault of the cra
anterior and middle cranial fossæ, and the superior fossæ of th
bone. The cerebral hemispheres are united together by a
missure termed the corpus callosum, and by smaller commissu

THE MEDULLA OBLONGATA.

EXTERNAL CHARACTERS.

The *medulla oblongata* is continuous below with the spinal
level with the lower margin of the foramen magnum. Its upp

bundles of the pyramids ; the posterior fissure is continued upwards about the middle of the medulla where it expands into the fourth ventricle.

The structure of the medulla oblongata will be most easily made out by tracing the several parts of the spinal cord upwards in their continuity with the parts of the medulla oblongata.

Fig. 259.

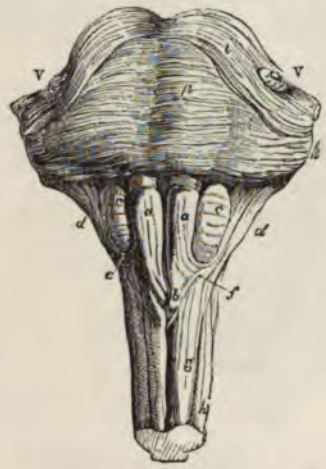


Fig. 259.—VIEW OF THE ANTERIOR SURFACE OF THE PONS VAROLII AND MEDULLA OBLONGATA, WITH A SMALL PART OF THE SPINAL CORD ATTACHED.

a, *a*, pyramids ; *b*, their decussation ; *c*, *c*, olives ; *d*, *d*, restiform bodies ; *e*, external arciform fibres, curving round the lower end of the olive ; *f*, fibres described by Solly as passing from the anterior column of the cord to the cerebellum ; *g*, anterior column of the spinal cord ; *h*, lateral column ; *p*, pons Varolii ; *i*, its upper fibres ; V, V, roots of the fifth pair of nerves.

In doing this it will be found that the relative position and extent of many of the parts are gradually altered, and that other parts which are not, so far as is known, represented in the spinal cord become interpolated between those which are there met with. It will further be found that the change of relative position of the parts is largely owing to two causes. In the first place the sudden passage of large bundles of medullated fibres from the posterior part of the lateral column of the cord to the opposite side of the anterior median fissure appears to break up to a great extent the grey matter of the anterior cornu, which is traversed by the bundles. In the second place the opening up of the central canal and separation of the lips of the posterior median fissure bring the grey matter to the surface in the fourth ventricle, whilst the posterior cornu is coincidently shifted to the side, much in the same way as it would be if a median incision were made from the posterior surface of the spinal cord into the central canal, and the two lateral halves were then turned outwards so that the sides of the posterior median fissure became the posterior surface of the cord.

In tracing the parts of the spinal cord upwards into the medulla in the manner proposed, we may employ the lines along which the cranial nerve-roots issue from the sides of the medulla as guides in recognizing in the latter the three chief columns which are marked off on the surface of the cord by the exit of the spinal nerve-roots. It will be found that the *line of the posterior or sensory roots* of the spinal nerves is prolonged for a certain distance by a series of bundles of the spinal accessory or eleventh cranial nerve(figs. 260, 261, *XI*). This begins to take origin as far down as the lower end of the cervical region of the cord (fig. 244, 8), but there its roots issue more from the side, and external to the posterior roots of the cervical nerves. At the upper end of the cervical region however, they approach the line of the posterior roots, and indeed some of the bundles arise in conjunction with those of the first and sometimes of the second cervical nerve, after which, as just

, they prolong the line of the posterior roots.
ng this line by the bundles of the vagus root
again by those of the glossopharyngeal (*IX*).

Fig. 260.

-VIEW FROM THE MEDULLA , PONS VA- RA CEREBRI, CENTRAL POR- HE ENCEPHA- len Thomson) SIZE.

ght side the of the central l of Reil have gether with a f the anterior volutions: on e these have d by an inci- between the ticus and the isphere. lfactory tract nd lying in II, the left in front of ure; II', the act; *Th*, the of the left ticus; C, the or island of ssure of Syl- anterior per- ; *e*, the ex- , the internal ulatum; *h*, is cerebri or ly; *tc*, tuber h the infun- , one of the antia; P, the uncle or crus; III, close to motor nerve; terior perfo-

wing letters refer to parts in connection with the medulla oblongata and pons. PV, *V*, the greater root of the fifth nerve; +, the lesser or motor root; *VI*, ve; *VII*, the facial; *VIII*, the auditory nerve; *IX*, the glossopharyngeal; mogastric nerve; *XI*, the spinal accessory nerve; *XII*, the hypoglossal the suboccipital or first cervical nerve; *p a*, pyramid; *o*, olive; *d*, anterior e of the spinal cord, above which the decussation of the pyramids is repre- anterior column of cord; *r*, lateral tract of medulla continuous with, *c l*, lumn of the spinal cord.

of these nerves deeply into the medulla, they are found to or from collections or columns of nerve-cells which lie in r derived from the posterior cornu of the cord. They corres- morphologically, and in a measure physiologically, to the

posterior roots of the spinal nerves, and their line of exit ... the postero-lateral groove of the cord and indeed is marked at ... a shallow sulcus continuous with that groove. If this line be ... upwards (fig. 261) it will be seen that the sulcus is obliterated or ... before long, so that the issuing bundles of nerve-roots alone serve ... its position. As it passes upwards it becomes gradually more ... from the middle line, turning outwards; so that opposite the place ... the central canal opens into the calamus scriptorius of the ... ventricle, the line in question has left the posterior surface and ... rest of its course runs along the lateral surface of the medulla. ... the upper end it passes near the posterior margin of an oval promi... on the surface of the medulla termed the *olivary body* (*o*), but is sep... from that prominence by a narrow tract. In transverse sections of ... lower part of the medulla oblongata (fig. 262) it is seen that the ... of fibres of the nerve-roots, in traversing the substance of the me... to reach the grey matter near the central canal mark off a somewhat ... area on each side at the posterior part of the section. This area is ter... by Flechsig the *posterior area of the medulla*, and the tracts of ... fibres which can be traced, as will be immediately noticed, upon ... surface of this part, may therefore be conveniently termed its *post... columns*. They correspond in position to the posterior columns (poste... median column, and posterior lateral column) of the spinal cord.

The *line of origin of the anterior roots* of the spinal nerves is ... marked in the spinal cord by a distinct furrow like that from which ... posterior roots issue. But the same line, when traced upwards into ... medulla, deepens into a well-marked longitudinal groove which is co... tinued almost vertically as far as the lower border of the pons. In ... upper part this groove separates the olivary prominence from the ... minence of the pyramid. Just below the olivary body it is often obl... rated for a certain part of its course by a band of transverse fibres. T... root-bundles of the hypoglossal nerve (figs. 260, 261, *XII*) pass ... from this furrow, and in transverse sections of the medulla they may ... traced back through the substance of the organ to a group or column ... nerve-cells situated in a portion of grey matter close to the antero-late... side of the central canal in the lower closed part of the medulla (fig. 26... and close to the middle of the fourth ventricle in the upper opened-out ... part (fig. 268). This portion of grey matter is continuous below with ... part of the anterior cornu, so that the roots of the hypoglossal, both in ... their deep origin and in their place of exit, correspond with the anterior ... roots of the spinal nerves. In traversing the substance of the medulla they ... mark off an *anterior area*, wedge-shaped in transverse section, which is ... placed between them and the anterior median fissure (fig. 262, *f*). This ... area is on the surface marked by the prominence known as the *pyramid* or ... *anterior pyramid*, which corresponds in position (but only to a small extent ... in the fibres of which it is composed) with the anterior column of the spinal ... cord. The remainder of the transverse section of the medulla, after the ... posterior and anterior areas are deducted, lies between the line of nerve-... root bundles of the hypoglossus and that of the successive bundles of ... the spinal accessory, vagus and glosso-pharyngeal. This is termed by ... Flechsig the *lateral area*, and on the surface it is marked below by a ... continuation of part of the lateral column of the cord, and above by the ... olivary prominence already alluded to.

We may now proceed to describe in detail the several parts which

upon the surface of the medulla in the three regions thus marked the two sets of nerve roots, commencing with the posterior

Fig. 261.

Fig. 261.—VIEW OF THE MEDULLA OBLONGATA, PONS VAROLII, CRURA CEREBRI, AND CENTRAL PARTS OF THE ENCEPHALON FROM THE RIGHT SIDE. (Allen Thomson.)

The corpus striatum and thalamus opticus have been preserved in connection with the central lobe and crura cerebri, while the remainder of the cerebrum has been removed.

St, upper surface of the corpus striatum ; *Th*, back part of the thalamus opticus ; C, placed on the middle of the five or six convolutions constituting the central lobe or island of Reil, the cerebral substance being removed from its circumference ; *Sy*, fissure of Sylvius, from which these convolutions radiate, and in which are seen the white striæ of the olfactory tract ; I, the olfactory tract divided and hanging down from the groove in the convolution which lodges it ; II, optic nerves a little way in front of the commissure ; *a*, right corpus albicans with the tuber cinereum and infundibulum in front of it ; *h*, hypophysis or pituitary body ; *e*, external, and *i*, internal corpus geniculatum at the back part of the optic tract ; P, peduncle or crus of the cerebrum ; III, right oculo-motor nerve ; *p*, pineal gland ; *q*, corpora quadrigemina ; IV, trochlear nerve rising from *v*, the valve of Vieussens.

The following numbers and letters refer chiefly to parts in connection with the medulla and pons. V, placed on the pons Varolii above the right nervus trigeminus ; *s*, the superior, *m*, the middle, and *in*, the inferior peduncle of the cerebellum cut short ; VI, the sixth nerve ; VII, facial nerve ; VIII, auditory nerve ; IX, the glosso-pharyngeal nerve ; X, placed opposite to the cut end of the pneumo-gastric nerve ; and XI, the uppermost fibres of the spinal accessory nerve ; XII, the hypoglossal nerve ; *p a*, pyramid ; *o*, olive ; *a r*, arciform fibres ; *r*, restiform body ; *tr*, tubercle of Rolando ; *c a*, anterior, *c p*, posterior, and *c l*, lateral columns of the spinal cord ; *C I*, *C i*, anterior and posterior roots of the first cervical nerve.

Fig. 262.

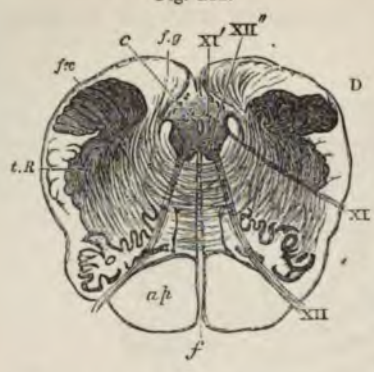


Fig. 262.—SECTION ACROSS THE MEDULLA OBLONGATA A LITTLE BELOW THE OBEX OF THE CALAMUS SCRIPTORIUS (Jackson Clarke).

c, central canal; *f*, anterior median fissure; *f.g.*, funiculus gracilis; *f.c.*, funiculus cuneatus; *t.R*, tubercle of Rolando; *o*, olivary body; *a.p*, pyramid; XI, XII, spinal accessory and hypoglossal nerves; XI', XII', their nuclei.

Posterior columns. It will be remembered that in the upper region of the spinal cord a small portion of the whole posterior column is marked off from the rest by a well-developed pia-matral septum, and is indicated in the surface by a distinct longitudinal prominence bounded laterally by a shallow groove. The portion thus marked off is the postero-

Fig. 263.

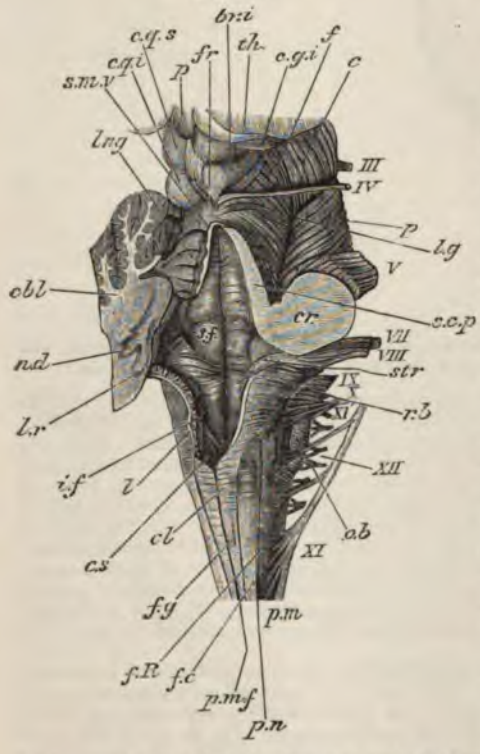


Fig. 263.—POSTERIOR AND LATERAL VIEW OF THE MEDULLA OBLONGATA, FOURTH VENTRICLE AND MESENCEPHALON (E. A. S.). NATURAL SIZE.

The cerebellum and inferior medullary velum, and the right half of the superior medullary velum, have been cut away, so as to expose the fourth ventricle.

p.n., line of the posterior roots of the spinal nerves; *p.m.f.*, posterior median fissure; *f.g.*, funiculus gracilis; *cl.*, its clava; *f.c.*, funiculus cuneatus; *f.R.*, funiculus of Rolando; *r.b.*, restiform body; *c.s.*, lower end of the fourth ventricle (calamus scriptorius); *l*, section of the ligula or tænia; part of the choroid plexus is seen beneath it; *l.r.*, lateral recess of the ventricle; *str.*, striæ acusticæ; *i.f.*, inferior (posterior) fovea; *s.f.*, superior (anterior) fovea; between it and the median sulcus is the funiculus teres; *cbl.*, cut surface of the left cerebellar hemisphere; *n.d.*, central grey matter (nucleus dentatus) seen as a wavy line; *s.m.v.*, superior (anterior) medullary velum; *lng.*, lingula; *s.c.p.*, superior cerebellar peduncle cut longitudinally; *cr.*, combined section of the three cerebellar peduncles (the limits of each are not marked); *c.q.s.*, *c.q.i.*, corpora quadrigemina (superior and inferior); *fr.*, frænulum; *f*, fibres of the fillet, seen on the surface of the tegmentum; *c*, crusta; *l.g.*, lateral groove; *c.g.i.*, corpus geniculatum internum; *th.*, posterior part of thalamus; *p*, pineal body. The roman numbers indicate the corresponding cranial nerves.

en the posterior median column and the postero-lateral groove
ich the posterior roots of the cervical nerves pass out there is found
pper part of the cord a single distinct column, viz., the posterior
olumn. This is also the condition at the lowest part of the
close to its junction with the cord. But very soon there begins
nterpolated between the prolongation of this column and the
in question another longitudinal prominence which is at first
but soon broadens out into a considerable eminence known as the
of Rolando. The longitudinal prominence which passes up into it,
d therefore by Schwalbe, the *funiculus of Rolando* (fig. 263, *f.R.*).
ay be regarded as the prolongation of the posterior lateral column
dually expands as it ascends, so that it has a somewhat wedge-like
d it is accordingly known as the *cuneate funiculus* (*f.c.*). On a
th the adjoining clava of the funiculus gracilis, the enlarged part of
eate funiculus also, like that, exhibits a slight eminence, which
marked in children, and has been termed the *cuneate tubercle*
be). Beyond this the cuneate funiculus passes the clava, and
n forming the lateral boundary of the fourth ventricle.

niculus of Rolando is termed by Henle the lateral cuneate funiculus ; it
ed, as we shall presently see, by the approach of the caput cornu
is to the surface.

e upper part of the medulla oblongata, the cuneate funiculus is
ed by a set of fibres (*external arciform or arcuate fibres*) which
m the anterior median fissure and passing transversely outwards
rface of the anterior pyramids and olivary body, turn upwards to
restiform body. There is also a narrow strand of fibres marked
hite appearance which crosses the line of the posterior roots from
al column, just above the level of the tubercle of Rolando, and
is tract of oblique fibres. This is the *lateral cerebellar tract*
as been already noticed in the description of the spinal cord.
bliquely crossing fibres turn upwards as they cross the funiculus

into the cerebellum, and this is mainly constituted as will be presently [illegible] by the arched fibres above mentioned, reinforced by the lateral cerebellar [illegible] the fibres in the cuneate funiculus and funiculus of Rolando being [illegible] probability not continued up into the cerebellar peduncle, as from the [illegible] those funiculi sometimes appear to be.

Fig. 264.

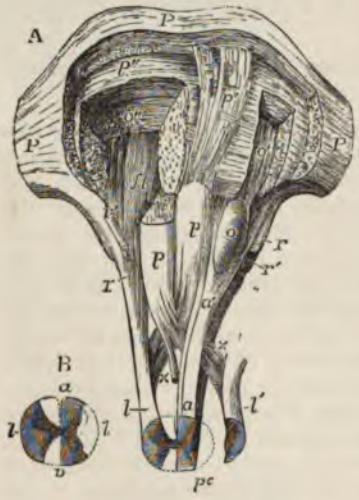


Fig. 264.—DISSECTION OF THE [illegible] OBLONGATA AND PONS SHOWING [illegible] COURSE OF THE PYRAMIDAL TRACT [illegible] THEM. (Allen Thomson.)

P, pons Varolii; *p*, the pyramids, [illegible] upper part of the right one has been [illegible] away; *p'*, the fibres of the left pyramid [illegible] they ascend through the pons, exposed [illegible] removal of the superficial transverse [illegible] *p''* is placed on some deeper transverse [illegible] fibres of the pons on the right side, [illegible] the divided fibres of the right pyramid [illegible] left anterior column of the cord, its [illegible] part passes upwards into the outer part [illegible] the pyramid, the remainder dips beneath [illegible] pyramid and olivary body; *o*, olivary [illegible] body; *o'*, the continuation of part of the lateral column ascending through the pons and exposed by the removal of a small portion of the deeper transverse fibres; *o''*, some of the same fibres divided by a deeper incision on the right side; *l*, *l'*, the lateral columns of the cord; *r*, [illegible] deeper parts passing by decussation into the pyramids; *r'*, direct cerebellar tract passing from the lateral column into the inferior peduncle of the cerebellum, or restiform body; *r'*, fasciculus passing from the anterior column to the same; *ft*, deep longitudinal fibres derived from the anterior and lateral columns of the cord.

B, explanatory outline of the section of the spinal cord. *a*, anterior column; *p*, posterior; *l*, lateral.

Lateral columns.—The lateral column of the spinal cord appears, on the surface, to be directly continued upwards into the lateral column of the medulla oblongata. In reality, however a considerable tract of the white fibres—that which in the spinal cord we have noticed as the lateral pyramidal tract—is found, at the lower end of the medulla, to cross obliquely in stout bundles through the grey matter of the anterior cornu, and across the anterior median fissure to the other side of the medulla, where they form the mesial and larger part of the pyramid. The rest of the lateral column can be traced vertically upwards (with the exception of the lateral cerebellar tract which passes, as already indicated, backwards into the restiform body) as far as the lower end of the olive where its longitudinally coursing fibres become concealed by this prominence and by the arched fibres already noticed.

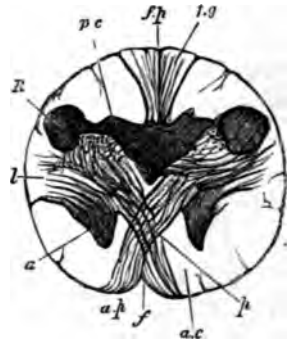
The **olivary body** (figs. 260, 261, *o*) is, as its name implies, an olive-shaped prominence, which lies in the upper part of the medulla immediately above the apparent termination of the lateral column, and extending nearly as far as the lower border of the pons, being only separated from this by a deep groove in which is sometimes a small band of arched fibres. The line of exit of the hypoglossal nerve-roots lies on its inner or mesial border, that of the accessory, vagus and glossopharyngeal roots along its outer side, but the latter are separated from it by a groove in

longitudinal fibres prolonged from the lateral tract can be seen. times there is a small longitudinal tract running along its inner also, and in such case, with the arched fibres above and below, olive appears to be entirely enclosed by a fibrous strand, which has times been described as its capsule (*siliqua olivæ*). The longitudinal before and behind the olive are often concealed in great measure e arched fibres, which may form a complete superficial layer over olive, and indeed over the whole anterior and lateral surface of this part of the medulla.

nterior columns. Pyramids of the medulla.—The anterior ns of the cord, although on superficial inspection they appear to rolonged into the pyramids of the medulla, are so only to a small t. For the lateral pyramidal tract, crossing the anterior median re from the lateral column, is continued upwards close to that re, and unites with the comparatively small anterior pyramidal tract nstitute the prominence known as the *pyramid*. The prolongation rds of the rest of the anterior column of the cord lies deeply, being ether concealed from view by the pyramids.

he pyramids (fig. 260, *pa*), are broader and more prominent above than w. They are bounded internally or mesially by the anterior median fis-

Fig. 265.



. 265.—SECTION OF THE MEDULLA OBLONGATA AT THE MIDDLE OF THE DECUSSATION OF THE PYRAMIDS (Lockhart Clarke).

, anterior; *f.p.*, posterior fissure; *a.p.*, pyramid; mains of part of anterior cornu, separated by crossing bundles from the rest of the grey matter; ntinuation of lateral column of cord; *R*, con-ation of substantia gelatinosa of Rolando; *p.c.*, inuation of posterior cornu of grey matter; *f.g.*, iculus gracilis.

re, and externally by the olivary bodies, ing separated from these by the groove ire mentioned, from which the roots the hypoglossal nerve issue. At their per end they are constricted, and thus for the substance of the pons, through nich their fibres may be traced into the peduncles of the cerebrum.

The *decussation of the pyramids* is the name given to the obliquely ssing bundles of the lateral pyramidal tract which are seen in the terior median fissure at the lower part of the medulla. The extent to nich the decussation is visible varies considerably in different dividuals; for in some the bundles take a deeper, in others a more perficial course. Further, in some cases a larger share than usual of e longitudinal fibres of the pyramids passes down in the anterior ramidal tract and a correspondingly smaller share in the lateral ramidal tract. And since the anterior tract, which in the pyramid external to the lateral tract, does not cross in the medulla but merely ses obliquely at its lower end to attain the side of the anterior median sure, the decussation in these cases is of less extent. On the other nd, in rare cases, the whole of the fibres of the anterior pyramid may oss over at the lower part of the medulla and become lateral pyramidal act, in which case the anterior or uncrossed tract is wanting in the

cord, and the medullary formation is very well marked. A are found between these two cornua (see p. 279).

Medullary portion of the fourth ventricle.—The r
raters of the medulla oblongata may be compared to a deer
part of it which enters into the formation of the floor of the fo
This is the space into which the central canal of the cord al
somewhat enlarged and cell-like, opens out on the poste
aspect of the medulla (fig. 263). The opening-out seems to
the divergence of the funiculi graciles on either side as we ad
the lateral boundaries of the ventricle curve round with re
towards the ventricle, and the latter rapidly broadens ou
the middle peduncle of the cerebellum it has attained its g
From this point its upper part again narrows, converg
above to be continued into the comparatively narrow fore
The ventricle is therefore irregularly lozenge- or diamond-s
sometimes named *fossa rhomboidalis*. The pointed lowe
ventricle has the shape of a writing pen, and is termed the c
taenia (fig. 266). At its widest part the fourth ventricle is
a short distance on either side between the cerebellum and m
these come in contact, in the form of the pointed *lateral re*
lateral boundaries of the ventricle in its lower or medullary
clavæ of the funiculi graciles, the funiculi cuneati, and
bodies. The roof or posterior wall is formed by a simple lay
epithelium covered by pia mater; but it is not quite compl
is a hole in it termed the *foramen of Majendie* a little abo
where the central canal opens out into the ventricle, and t
other apertures in the epithelial roof in the lateral recesses jus

Fig. 266.

Fig. 266.—Anterior boundary (floor) of the fou
(E.A.S.). Natural size.

m.s., median sulcus; *str.*, striæ acusticæ, mar
between the upper part of the ventricle and the l
part or calamus scriptorius; *l.r.*, lateral recess; *i.f.*
terior) fovea; *a.c.*, ala cinerea; *t.a.*, acoustic t
superior (anterior) fovea, close to the lateral margin
part of the ventricle.

At the sides and below, this layer of epith
into continuity with the epithelium coveri
but it is somewhat thickened by the addit
nervous matter before reaching the lateral b
the floor. This thickening is left as a slightl
and often ragged membrane when the epithelium of the roof of
is torn off with the pia mater. It commences at the apex of th
accompanies the lateral boundary for a short distance; then tu
surface of the restiform body and terminates close to the
whence the roots of the vagus and glosso-pharyngeal nerves
termed the *taenia* or *ligula* (figs. 263, 266, *l*), and its upper tra
forms the lower boundary of the lateral recess of the ventric
thickening in the epithelial membrane is sometimes seen at
the ventricle roofing over the point of the calamus scriptor
named the *obex*.

Two longitudinal vascular inflexions of the pia mater, k
choroid plexuses of the 4th ventricle, project from the m

on either side of the middle line, covered everywhere, however, by thelium of the roof. Offsets from these pass also into the lateral s (fig. 263), from the apices of which they emerge, encircled by ature of the ligula, which was termed by Bochdalek the *cornu*-. The epithelial layer of the roof of the ventricle follows all the tions of the choroid plexuses, but is nowhere pierced by them; nerally described as the epithelium of the plexuses.

part of the floor of the 4th ventricle which belongs to the descrip- the medulla oblongata is marked off superiorly by some transverse lines, which cross the grey matter of the floor, and are known as *riæ medullares seu acusticæ* (fig. 266, *str*). These arise close to dian line, and curve outwards over the restiform bodies to join ots of the auditory nerve. They sometimes form a tolerably ct bundle, sometimes are more separate from one another, and nally are not to be made out on the surface, probably in these having a deeper course.

e lower and smaller part of the floor of the ventricle is bisected by t median groove. A little on either side of this groove and imme- y below the striæ medullares, is a small triangular depression (*inferior*, fig. 266, *i.f.*), the apex of which extends only as far as the striæ, he base is prolonged into two grooves extending one from each . The inner of the two grooves passes with a slightly curved course rds the point of the calamus scriptorius, and thus cuts off a pointed gular area), which is bounded mesially by the median sulcus, he base of which is turned towards the striæ acusticæ. This area htly prominent, and constitutes the lower end of what will presently scribed as the fasciculus teres; in it is the prolongation of the of nerve-cells from which the roots of the hypoglossal nerve take n. The groove which is prolonged from the outer angle of the fovea, s downwards with a slight outward obliquity nearly to the lateral dary of the ventricle, and marks off externally another triangular the base of which is also directed upwards, where it can be traced a prominence, (best marked in children) over which the striæ icæ course (*t.a.*). To this prominence Schwalbe has given the name *culum acusticum*, since the main part of the auditory nerve arises in ction with it and with the triangular lateral area behind.

cluded between the two grooves is a third triangular area, the apex hich is at the inferior fovea, while its base looks downwards utwards. This area has a distinctly darker colour than the rest of oor of the ventricle, and especially than the funiculi teretes on the side, which have a whitish grey appearance, and it has accordingly named the *ala cinerea* (*a.c.*). Towards the apex it is somewhat sed, but below it is elevated into a distinct prominence (*eminentia a*). It contains the nucleus of the vagus, and superiorly, near the , of the glosso-pharyngeal nerve.

INTERNAL STRUCTURE OF THE MEDULLA OBLONGATA.

e internal structure of the medulla, like the external form, will st understood by tracing its several parts upwards from the spinal ; and this can be most readily done by a comparison of the ap- nces of successive transverse sections.

The first changes are produced, both in internal structure and in external form, by the passage of the fibre-bundles of the lateral pyramidal tract obliquely through the grey matter of the anterior cornu, across the anterior median fissure to the pyramid of the opposite side (fig. 265). By this abrupt passage of a large number of white fibres through it, the anterior cornu is broken up, and one part, the caput cornu (*a*), is entirely separated from the rest of the grey matter; while only the base of the cornu remains, as a small portion of grey matter close to the antero-lateral aspect of the central canal.

The separated portion of the anterior cornu becomes pushed over to the side by the development of the pyramid and the interpolation higher up of the olivary body between them, so that it comes to lie close to the remains of the posterior cornu (see below). The greater part of its substance is broken up into a *formatio reticularis* (fig. 267, *f.r.*), i.e. a comparatively coarse network of grey matter containing nerve-cells intersected by bundles of white fibres; but a small part of the cornu remains for a time in the lateral column, near the surface, and is known as the nucleus of that column (*nucleus lateralis*, (fig. 267, *n.l.*)).

Meanwhile the posterior cornua become gradually shifted laterally, simultaneously with an increase in size of the posterior columns of the

Fig. 267.

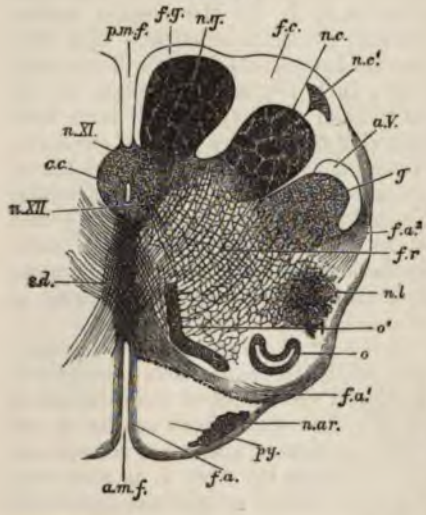


Fig. 267. SECTION OF THE MEDULLA OBLONGATA IN THE REGION OF THE SUPERIOR PYRAMIDAL DECUSSATION. (Schwalbe.) $\frac{4}{1}$

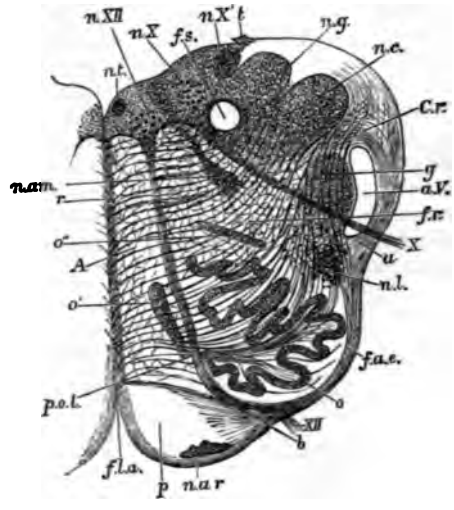
a.m.f., anterior median fissure; *f.a.*, superficial arciform fibres emerging from the fissure; *py.*, pyramid; *n.ar.*, nucleus of the arciform fibres; *f.a'.*, deep arciform fibres becoming superficial; *o.*, lower end of olivary nucleus; *o'.*, accessory olivary nucleus; *n.l.*, nucleus lateralis; *f.r.*, formatio reticularis; *f.a.*², arciform fibres proceeding from formatio reticularis; *J.*, substantia gelatinosa of Rolando; *a.V.*, ascending root of fifth nerve; *n.c.*, nucleus cuneatus; *n.c'.*, external cuneate nucleus; *f.c.*, funiculus cuneatus; *n.g.*, nucleus gracilis; *f.g.*, funiculus gracilis; *p.m.f.*, posterior median fissure; *c.c.*, central canal surrounded by grey matter, in which are, *n.XI.*, nucleus of the spinal accessory, and, *n.XII.*, nucleus of the hypoglossal: *s.d.*, superior pyramidal decussation.

medulla, so that in place of forming an acute angle with the posterior median fissure, they now lie almost at right angles to it (fig. 265). Moreover, the caput cornu enlarges and comes close to the surface, where it presently forms a distinct projection, the funiculus of Rolando, which, a little higher up, swells into the tubercle of Rolando (fig. 265, R.). At the same time the cervix cornu diminishes in size and like the anterior cornu is eventually broken up by the passage of transverse and longitudinal bundles of white fibres through it, into a reticular formation, which then separates the caput cornu posterioris (fig. 267, *g.*) from the

ıe grey matter, and joins the reticular formation derived from ior cornu. In the tubercle of Rolando the caput cornu is close rface, and its grey substance can readily be seen, but above the it lies deeper, being covered by a well-marked bundle of r white fibres (ascending root of the 5th nerve (*a. V.*)) and ılique arched fibres which are passing over it to form the restiform

grey matter of the base of the posterior cornu undergoes a ıble increase as we trace it upwards in sections. For portions natter are soon found to extend from it into the funiculi graciles eati, forming the so-called nuclei of those columns (figs. 267, , *n.c.*). These nuclei are at first narrow in transverse section;

Fig. 268.



SECTION OF THE MEDULLA OBLONGATA AT ABOUT THE LEVEL OF THE OLIVARY BODY. (Iba.) ½

nterior median fissure; ıcleus arciformis; *p.*, *XII.*, bundle of hypo- rve emerging from the at *b*, it is seen coursing the pyramid and the cleus, *o.*; *f.a.e.*, exter- rn fibres; *n.l.*, nucleus *a.*, arciform fibres owards restiform body ough the substantia gel- ., partly superficial to ding root of the 5th *V.*; *X.*, bundle of vagus ging; *f.r.*, formatio re- *c.r.*, corpus restiforme, to be formed, chiefly n fibres, superficial and *c.*, nucleus cuneatus; eus gracilis; *t.*, attach- e ligula; *f.s.*, funiculus ; *n.X.*, *n.X'.*, two parts us nucleus; *n.XII.*, hypoglossal nucleus; *n.t.*, nucleus of the funiculus teres: ıcleus ambiguus; *r.*, raphe; *A.*, continuation of anterior column of cord; *o'*,*o''*, olivary nuclei; *p.o*, pedunculus olivæ.

he central canal approaches the posterior surface of the medulla ear as comparatively thick masses, which produce externally the es of the clava and the cuneate tubercle. Outside the nucleus ınículus cuneatus (which is often known as the restiform nucleus) accessory or external nucleus becomes formed (fig. 267, *n.c'.*).

the slit-like upper end of the central canal opens out into the tricle, the small remaining portion of the base of the anterior omes to the surface of the floor of the ventricle, and as the are traced forward increases gradually in size, producing the e of the funiculus teres. In it, both in the lower part of the where the canal is still closed and above where it has opened out, of large nerve-cells (*n.XII.*) is seen in the transverse sections, ting a longitudinal vesicular column. From this column of cells essive bundles of the roots of the hypoglossal or 12th cranial ise and pass obliquely through the substance of the medulla to

leave it on its anterior aspect. The tract of nerve-cells is a known as the **hypoglossal nucleus.**

In the 4th ventricle the hypoglossal nucleus lies a shor from the surface. Nearer to the surface of the floor and ne the median groove is a small group of cells continuous with t in the raphe, presently to be described, and known someti nucleus of the funiculus teres (fig. 268, *n.t.*).

At the base of the posterior cornu in the lower part of the n near the central canal, a group of cells (fig 267, *n. XI.*) is see which seems to correspond with the hypoglossal group in the anterior cornu. This, if traced upwards, is found to be pushed as the central canal opens, so that in the floor of the ventricle side the hypoglossal nucleus (fig. 268, *n.X.*). The group of cells in question corresponds to the prominence of the ala ci appears on the surface, and it extends forwards as far as the terior. From it there arise successively bundles of fibres of the spinal accessory, vagus and glosso-pharyngeal nerves (11t 9th cranial nerves) : those of the upper roots of the spinal acc lower part of the medulla where the canal is still closed ; those beginning at the commencement of the ventricle, and arisin length of the eminentia cinerea ; and those of the glosso-pharyn for the most part from the upper part of the ala cinerea, an posterior fovea. The column of cells in question forms then the **nucleus of the spinal accessory, pneumogastric a pharyngeal nerves.**

Fig. 269.

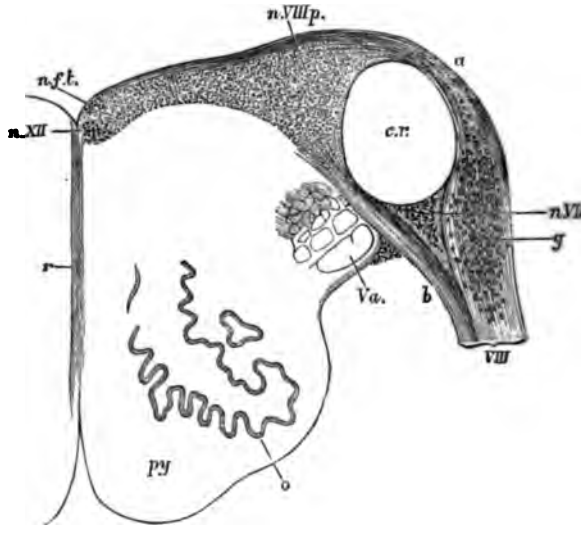


Fig. 269. TRANSVERSE SECTION OF THE UPPER PART OF THE MEDULLA (Schwalbe.) 1

py., pyramid ; *o.*, olivary nucleus ; *V.a.*, ascending root of the fifth n inferior (posterior) root of the auditory nerve, formed of two parts, *a.* a enclose the restiform body, *c.r.* ; *n. VIII.p.*, principal nucleus of the au *n. VIII.ac.*, accessory nucleus ; *g.*, ganglion cells in the root ; *n.f.t.*, a funiculus teres ; *n.XII.*, nucleus of the hypoglossal ; *r.*, raphe.

wards the upper part of the medulla another tract of cells becomes ped outside the line of the accessory, vagus, and glosso-pharyngeal . This tract corresponds to the lateral triangular area which is seen e surface outside the ala cinerea, and which passes into the tuber- acusticum of Schwalbe. From it most of the fibres of the 8th or ory nerve take origin, and it is accordingly named the **principal ory nucleus.**

e nerve-cells in the hypoglossal nucleus are larger than those in inal accessory, vagal and glossopharyngeal nuclei. Those in the us of the funiculus gracilis are also of considerable size.

ucleus of the Olivary Body.—Besides those collections of grey er which are traceable from the grey matter of the spinal cord, ions occur in certain parts of the medulla oblongata, which are represented in the cord. Of these the most important is the *nucleus the olivary body*, which has been termed, from its appearance in ion, the *corpus dentatum of the olive* (fig. 268, *o*). It is enclosed the olivary prominence, and is therefore situated in the lateral area the medulla, but the grey matter is not visible from the surface, g covered by both longitudinal and transverse white fibres. It s the form of a thin wavy lamina, which is curved round at its s so as to form an ovoid scalloped capsule. The open part or hilus this looks towards the middle line and receives a considerable tract white fibres, which emanate from the anterior area immediately behind e pyramid, and pass into the hilus along its whole extent, forming e so-called *olivary peduncle* (*p.o.*). Under the microscope the nucleus pears as a wavy band of neuroglia, with small multipolar nerve- ls embedded in it. The fibres of the olivary peduncle diverge they pass to the grey lamina. They partly terminate in the axis- linder processes of its cells, and partly pass in small bundles through e lamina, those which are more posterior turning backwards and oursing obliquely (as internal arcuate fibres) through the posterior part of the lateral area to join the restiform body, whilst the others have a more direct course through the grey lamina and run between the longi- udinal fibres which cover the olive. On reaching the surface they bend ound and are continued as part of the layer of external arcuate fibres. ome may not reach the surface, but turn upwards and reinforce the ongitudinal fibres just mentioned.

Besides the main olivary nucleus two smaller isolated bands are generally seen (figs. 267, 268, *o'*, *o''*), looking like separated portions of the chief nucleus. They are situated one on the dorsal, and the other on the mesial aspect of the chief nucleus, and are known as the outer and inner *accessory olivary nuclei*. They are traversed like the main nucleus by bundles of internal arcuate fibres going to the restiform body, and are frequently connected at one or two places to the main nucleus. The inner accessory nuclei are sometimes termed the pyramidal nuclei, for they lie immediately behind the pyramid. The root-bundles of the hypoglossal nerves generally pass between them and the chief olivary nucleus after traversing the olivary peduncle, but sometimes the nerve pierces the chief nucleus near its mesial edge.

Other small collections of grey matter and nerve-cells are scattered in certain parts of the formatio reticularis, as well as one or two distinct tracts in connection with the external arcuate fibres, and a considerable amount in the median septum or raphe. These three structures may therefore next be described.

The **formatio reticularis** (figs. 267, 268, *f.r.*) occupies the whole of the anterior and lateral areas of the medulla, dorsal to the pyramids and olives respectively. It is thus named on account of the appearance which it presents in a transverse section viewed under a moderate magnifying power (fig. 270). This reticular appearance is caused by the intersection of bundles of fibres belonging to two sets which run at right

Fig. 270.

Fig. 270.—PART OF THE RETICULAR FORMATION OF THE MEDULLA OBLONGATA (Henle).

r.a., reticularis alba; *r.g.*, reticularis grisea; between them a root-bundle of the hypoglossus (*XII*). The longitudinal fibres of the reticular formation are cut across; the transversely coursing fibres are internal arcuate fibres, passing on the right of the figure towards the raphe.

to one another. Those of the one set are longitudinal, and these are intersected by transverse fibres, which pass obliquely from the raphe outwards and somewhat backwards with a curved course towards the funiculus graçilis and funiculus cuneatus, and the olivary nucleus; and also in the upper part of the medulla, towards the restiform body.

In some parts grey matter with nerve-cells enters into the constitution of the formatio reticularis. The cells are especially large and numerous in the reticular formation of the lateral area near the remains of the anterior cornu; and its grey matter is presumably derived in great

are from the latter. In the anterior or mesial area of the medulla, cells are absent from the formatio reticularis, and this is therefore mes distinguished as the *formatio reticularis alba* (fig. 270, *r.a.*), he other or *formatio reticularis grisea* (*r.g.*).

longitudinal fibres of the reticular formation of the anterior area (with ception of those which occupy the tract nearest to the pyramids), are pro- from the remainder of the anterior column of the spinal cord after the ge of the anterior (direct) pyramidal tract into the outer side of the pyramid. s nearest the pyramids are derived from arched fibres which issue from the of the funiculi graciles and from the olives, and turn longitudinally rds in this part. Those of the reticular formation of the lateral area are ged from the remains of the lateral column after the lateral pyramidal , and the lateral cerebellar tract have passed to their respective destinations. are added to as we trace them upwards in sections, the increase being due to the turning upwards of some of the inner curved fibres, or to the sion of fibres which are derived from nerve-cells in the grey matter near the erior surface, or in the grey reticular formation.

cording to Deiters, the axis-cylinder processes of the nerve-cells of the ular formation all pass downwards, while their branched processes are directed ntally.

The **arciform or arcuate fibres** of the medulla, which have been re than once alluded to, are the curved fibres which are seen in trans- se sections coursing in the plane of the section. From their position y are distinguished into external and internal, or superficial and deep. The *superficial arcuate fibres* (*f.a.e.* in fig. 268) emerge for the most rt from the anterior median fissure, and passing over the pyramids d olives, many of them go to the restiform body. They are added to deep fibres which come to the surface partly in the groove between pyramids and olives, partly after passing through the olives, as ore mentioned. Traced back in the anterior median fissure they are n to enter the raphe, and to cross over in it; after which it is sup- ed that they may become longitudinal, but their further course is not tainly known.

The *deep arcuate fibres* emerge from the raphe, and traverse the ckness of the medulla, tending towards the olives, the restiform body, l the nuclei of the cuneate and slender funiculi. As we have just n, those which pass through and in front of the olives are in continuity h the superficial arcuate fibres.

raced backwards into the raphe, the deep arcuate fibres appear to cross quely to the other side of the medulla, where in all probability they mostly me longitudinal, joining the fibres of the formatio reticularis alba. Others aid to turn upwards and become longitudinal before reaching the raphe. cells of the formatio reticularis grisea are probably connected with some of deep arcuate fibres.

Nuclei of the superficial arcuate fibres.—Amongst the superficial arcuate es, or between them and the subjacent columns of the medulla, small col- ions of grey matter with nerve-cells are here and there met with, which are inguished by the above name. The principal group of cells lies superficial to pyramid on either side (figs. 267, 268, *n.ar.*). The nerve-cells of these nuclei connected partly with the arciform fibres, partly with the fibres of the adja- t pyramid.

The **raphe** or septum (fig. 268, *r*) is composed of fibres which run part dorso-ventrally (fibræ rectæ), in part longitudinally, and in part

across the septum more or less obliquely. Intermixed amongst fibres are a number of nerve-cells in grey matter. The fibres continuous anteriorly with the superficial arched fibres, which the anterior median fissure; posteriorly with fibres from the graciles in the lower part, and from the nuclei of the funiculi the upper part of the medulla. The longitudinal are chiefly fi have passed into the raphe as fibræ rectæ or as superficial arcuate fibres, and in it have altered their direction and beco tudinal. The obliquely crossing fibres are the deep arched fib enter or emerge from the raphe. Others, however, near the do of the raphe seem to come from the nuclei of the nerve-roots, an may pass more directly across as commissural fibres either into t matio reticularis or into the pyramid of the other side, in either coming longitudinal. The nerve-cells of the raphe are multipol those in the middle being chiefly spindle-shaped. The latter nected with fibræ rectæ (Clarke), whilst the more laterally situat at least those near the anterior median fissure, are connected wi of the superficial arcuate fibres.

Course of nerve-fibres from the spinal cord upward t the medulla oblongata.—Assuming for convenience of descripti existence of three white columns of the spinal cord on each si various parts of these are continued upwards as follows :—

The *posterior column* forms in the medulla oblongata the substance of the three posterior funiculi ; viz. the f. gracilis, f. cu and f. Rolandi. The longitudinal fibres of the first two appear t in the grey matter which forms their nuclei ; and numerous deep a fibres enter or emerge from the same collections of grey matter.

The cuneate funiculus, has been commonly described as passing up int restiform body, but it seems doubtful if any of its fibres do actually take p the constitution of that body, although from the surface the funiculus in qu and the restiform body appear to be in continuity with one another.

A large part of the *lateral column* of the cord, viz., the l *pyramidal tract* (fig. 264, ×), passes into the opposite pyramid of medulla and ascends in this and in the ventral half of the pons to the peduncle of the cerebrum. Together with the small part of anterior column of the cord which also enters into the constitution the pyramid, it forms the *pyramidal tract of the encephalic isthmus* Flechsig (peduncular tract of Meynert). Some of the fibres of pyramid, however, emerge as external arcuate fibres, and joining restiform body pass to the cerebellum. A smaller part of the l column of the cord, the *direct lateral cerebellar tract* (fig. 264, *r*), pass at about the middle of the medulla obliquely backwards to join the restiform body.

The rest of the lateral column dips under the olives and forms the longitudinal fibres of the reticularis grisea. These are continued through the dorsal parts of the encephalic isthmus towards the corpora quadrigemina and optic thalamus.

The *anterior column* of the cord (fig. 264, *a*) in part is continued into the pyramid of the same side, but chiefly dips under the pyramid and forms the longitudinal fibres of the reticularis alba in the dorsal part of the mesial area. These pass upwards towards the cerebrum. In the pons Varolii one tract of them becomes collected into a well marked fasciculus

r longitudinal bundle), and most of the others form another t of the fillet) which terminates in the region of the corpora ina; the further destination of these will be afterwards noticed. ion of the medulla, they are indistinguishable from one another ult, but in the fœtus they are found to develope at different nd are then readily differentiated (Flechsig).

bundle of fibres of the anterior column of the cord was described by ssing obliquely upwards below the olive, to join the restiform body. t always present.

THE CEREBELLUM AND PONS.

art of the encephalon lies next above the medulla oblongata the upper part of the fourth ventricle. Unlike what is found ower part of the ventricle, where the dorsal wall or roof is formed by a prolongation of the epithelium which lines the floor and a this upper part of the ventricle the roof has become developed arge and complicated organ termed the cerebellum, which consists aller central part, and two large lateral hemispheres. These are around the ventral or anterior aspect of the cavity by a strongly bundle of fibres which issues on either side from the hemisphere o-called middle peduncle, and encircles and partly blends with practically a continuation upwards of the medulla oblongata, the orming a well-marked projection and thickening of the ventral the fourth ventricle, known as the *pons Varolii*. Two other pairs ncles issue from the lateral hemispheres of the cerebellum, the one passing downwards to the medulla, as the restiform body, er or superior pair of peduncles being directed upwards and s towards the cerebrum.

THE PONS VAROLII.

pons Varolii or *tuber annulare* forms a prominence marked by rse fibres above and in front of the medulla oblongata, and between ral hemispheres of the cerebellum (fig. 271). Its ventral surface per and lower margins are arched, the superior much more so than erior; and at the sides its transverse fibres are gathered together compact mass, which passes into the cerebellum, and is named the *crus or peduncle of the cerebellum*. Along the middle of its ventral the pons has a shallow groove along which the basilar artery nd it is perforated by small branches of the artery. The groove me measure due to the circumstance that the pyramids of the a in being continued up through the pons with a slightly diver- ourse produce a prominence on either side of the middle line, l however by the superficial transverse fibres.

pons consists ventrally of transverse or commissural fibres, between the longitudinal fibres prolonged upwards from the medulla ob- a pass; together with a large intermixture of grey matter. The cial fibres on the ventral surface (fig. 272, *po*^{2}) are transverse in eneral direction, but while the middle fibres pass directly across, ver set ascend slightly, and the superior fibres (fig. 271, *s*), which most curved, descend obliquely to reach the crus cerebelli on each ome of the upper fibres cross obliquely the middle and lower

ones, so as to conceal them at the sides. When the superfi
verse fibres are removed, the prolonged fibres of the anterior
come into view; these, as they ascend through the pons, are
into smaller bundles (figs. 272, 273, 274, *py*), intersected by ot
verse white fibres, which, with those upon the surface, are all c
into the middle peduncle of the cerebellum.

Fig. 271.

Fig. 271.—VIEW OF THE ANTERIOR
OF THE PONS VAROLII AND MEDULLA
GATA, WITH A SMALL PART OF THE
CORD ATTACHED

a, *a*, pyramids; *b*, their decussation;
olives; *d*, *d*, restiform bodies; *e*, exte
form fibres, curving round the lower ed
olive; *f*, fibres described by Solly as pas
the anterior column of the cord to the
bellum; *g*, anterior column of the spin
h, lateral column; *p*, pons Varolii; *i*, in
fibres; v, v, roots of the fifth pair of ner

At the lower part of the pons, b
the fibres from the anterior pyra
is a special set of transverse fibres
264, *p''*, fig. 272, *t*), named the t
zium—so called because in most of
lower animals, in which the more
trally situated fibres of the pons are
developed and the pyramids are
these transverse fibres partially sp
on the surface between the pyramid-bundles in an area of a somew
four-sided shape. Laterally they curve round a collection of grey ma
behind them, called the superior olivary nucleus (fig. 272, *o.s.*),
probably many of them are connected with its cells. They then co
outwards, across the bundles of the facial nerve-roots (*VII*), and in fr
of the upward prolongation of the substantia gelatinosa of the tub
of Rolando and the bundles of fibres belonging to the ascending roo
the fifth nerve (*a.V*), to join the middle peduncle of the cerebellum.

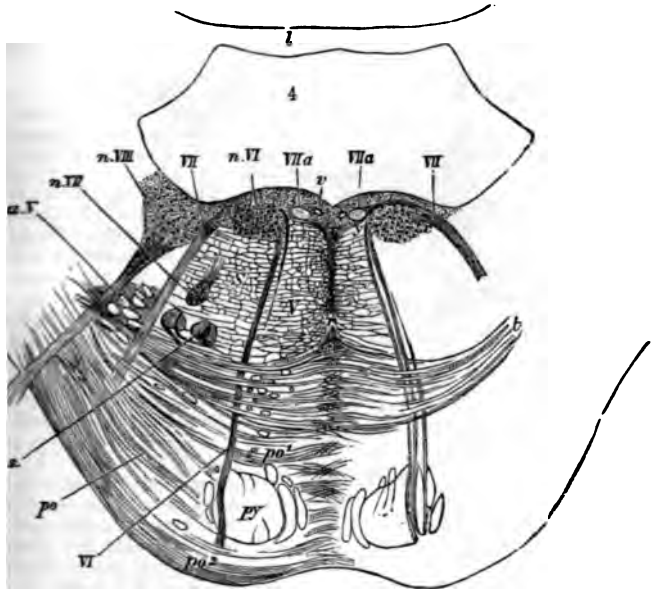
Between the bundles of fibres of this ventral portion of the pons
matter with small multipolar nerve-cells is everywhere found (*nuclei pon*
It is probable that many of the transverse fibres are connected with th
cells, and it may be that a cell is connected at one part with a transv
or commissural fibre, and at another sends a process to reinforce the
longitudinal fibres of the pyramidal tract ascending through the pons;
but the same fibres do not appear to turn upwards, for the transverse
fibres are smaller than the longitudinal. The interspersed grey matter
seems to correspond to that which is found between the arcuate fibres of
the medulla.

The posterior or dorsal portion of the pons is chiefly constituted by a
continuation upwards of the formatio reticularis and of the grey matter of
the medulla oblongata. As in the latter, there exists here also a median
septum or raphe, which is similar in structure to that of the medulla.
It does not extend through the ventral half, being obliterated, or nearly
so, by the great development of the transverse or commissural fibres,
except near the upper and lower borders where the superficial transverse

the pons turn in at the middle line; and especially at the upper here bundles of the same fibres encircle the crura cerebri as they from the pons.

reticular formation, in addition to the scattered and reticularly grey matter with nerve-cells everywhere met with, there are

Fig. 272.



—SECTION ACROSS THE PONS AT ABOUT THE MIDDLE OF THE FOURTH VENTRICLE (after Stilling and Schwalbe). ½

ramid-bundles continued up from the medulla; *po*, transverse fibres of the pons om the middle crus of the cerebellum, before (*po²*) and behind (*po'*) the chief bundles; *t*, deeper fibres of the same set, constituting the trapezium; the grey tween the transverse fibres is not represented either in this or in the following r, raphe; *o.s.*, superior olivary nucleus; *a. V*, bundles of the ascending root of nerve, enclosed by a prolongation of the grey substance of Rolando; *VI*, the sixth *VI*, its nucleus; *VII*, the facial nerve; *VIIa*, intermediate portion of the ve; *n. VII*, its nucleus; *VIII*, superior root of the auditory nerve; *n. VIII*, s outer or superior nucleus; *v*, section of a vein.

wo more important collections which lie embedded in this formd from which nerve-fibres arise. One of these is the superior nucleus, another is the nucleus of the seventh or facial nerve, ers give origin to portions of the fifth nerve.

superior olivary nucleus (fig. 272, *o.s.*) is a collection of small lls, which lies behind the outer part of the trapezium, in what orrespond (as indicated by the passage outwards of the roots of h and seventh nerves) to a prolongation of the lateral area of the . In man it is very much smaller than the inferior olivary , to which it does not present much resemblance. In some , however, it is larger, and has a distinctly sinuous outline. , as above mentioned, some of the fibres of the trapezium arise.

The **nucleus of the facial nerve** (*n.VII*) lies in the ret
tion just dorsal to the superior olivary nucleus, and at some
fore, below the floor of the fourth ventricle. It begins t
sections immediately above the medulla oblongata, and
or four millimeters upwards.

The **motor nucleus of the fifth nerve** (Lockhart Cl
nV') comes to view above that of the facial, but it is less de
lying a little below the lateral angle of the fourth ventr
and that of the facial contain large nerve-cells.

Fig. 273.

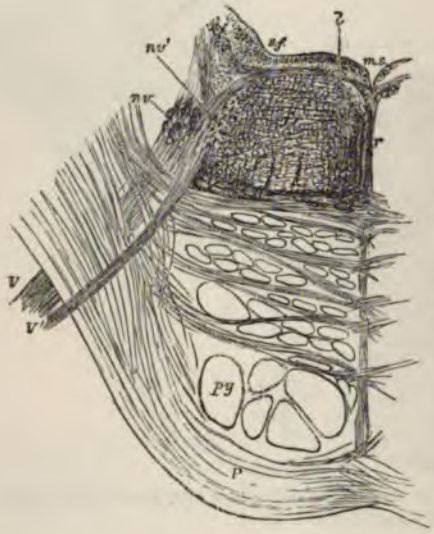


Fig. 273. — OBLIQ
SECTION OF THE
LINE OF EXIT TR
FIFTH NERVE (E

The section pas
lower part of th
(*n'V*) from which
of the motor root
a part of the uppe
(*nV*) is also show
in the form of a
isolated portions
Amongst these are
the ascending root
most of these hav
diverted outwards
in forming the iss
main or sensory roo
fibres near the fourt
come partly from
from a small longit
fibres (*l*) near the
(*m.s.*), and pass o
the root of the fi
formatio reticularis
substantia ferrugine

The **upper sensory nucleus of the fifth nerve** (*n.*
outer side of the motor root. The cells are small and arrang
separated by the fasciculi of origin of the nerve-root.
extends somewhat farther, both above and below, tha
nucleus.

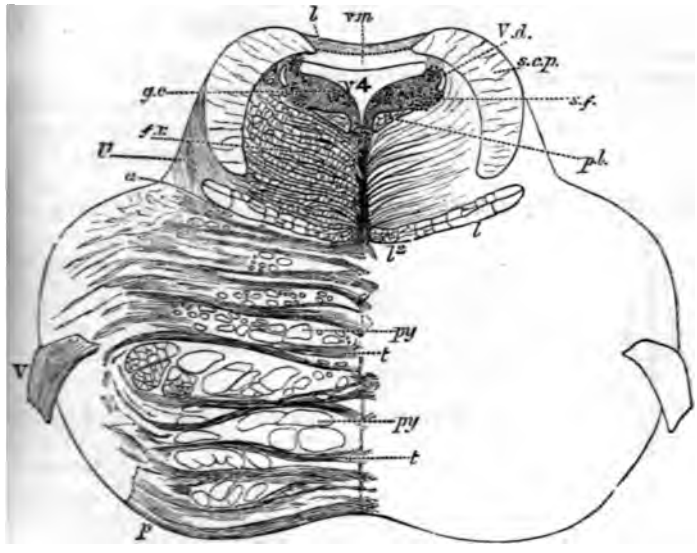
The rest of the grey matter of the pons lies near the
and appears in the floor of the upper part of the fou
Besides scattered nerve-cells, others are collected at certa
definite groups or nuclei from which some of the rem
nerves take origin. Like the similarly placed nuclei in
oblongata, these also do not lie close to the epithelium
the surface, but are separated from it by a layer of gelatin
(neuroglia) free from nerve-cells, termed the *ependyma* of t

The **inner** or **principal nucleus of the auditory ne**
n.VIII p.), which lies under the tuberculum acusticum,
upwards underneath the striæ acusticæ into the pons.
at about the junction of the medulla and pons, where it e
to the middle line; further up it rapidly narrows and be
towards the lateral boundary of the ventricle as the n

[illegible]erve makes its appearance between it and the median sulcus. [illegible] are small, and it is much broken up by the passage through it [illegible] transverse nerve-fibres.

[illegible]outer or **superior nucleus of the auditory nerve** (nucleus of [illegible], Laura) (fig. 272, *n.VIII*), is characterized by the large size of [illegible], and lies immediately on the outer side of the main nucleus. It [illegible] begin to be visible so far down as this, but is continued as far [illegible], rather increasing in size superiorly, whereas the main nucleus

Fig. 274.



274.—TRANSVERSE SECTION THROUGH THE UPPER PART OF THE PONS (Schwalbe, after Stilling). Rather more than twice the natural size.*

transverse fibres of the pons; *py*, *py*, bundles of the pyramids; *a*, boundary line [illegible]en the tegmental part of the pons and its ventral part; *l'*, oblique fibres of the [illegible] passing towards *l*, *l²*, longitudinal fibres of the fillet; *f.r.*, formatio reticularis; posterior longitudinal bundle; *s.c.p.*, superior cerebellar peduncle; *v.m.*, superior [illegible]llary velum; *l*, grey matter of the lingula; *v.4*, fourth ventricle; in the grey matter [illegible] bounds it laterally are seen, *V.d.*, the descending root of the fifth nerve, with its [illegible]s; *s.f.*, substantia ferruginea; *g.c.*, group of cells continuous with the nucleus of [illegible]peduct.

nishes. It is much broken up by longitudinal fibres. The con-[illegible]on of this nucleus with the auditory nerve is called in question by [illegible]a.

[illegible]e **accessory nucleus of the auditory nerve** is represented in the [illegible]r part of the medulla by a collection of nerve-cells lying in the angle [illegible]een the restiform body and the two portions of the posterior root of

*The details of this and of several of the preceding figures are filled in under a somewhat higher magnifying power than that used for tracing the outlines.

the nerve (fig. 269, *n.VIII.ac*). But the chief part of th placed higher up in the region of the pons on the outer anterior root. It is remarkable for the fact that its cell small and rounded but multipolar, are enclosed like those ganglia each in a nucleated capsule.

The **nucleus of the sixth nerve** (common nucleus of t seventh of some authors) consists of a tract or column of polar cells lying on either side of the median sulcus (fig. It corresponds to the part of the fasciculus teres which li the striæ acusticæ on the floor of the fourth ventricle. I relation to the root of the facial; which runs along its mesial curves round it eventually, and appears to receive some fi but it is somewhat doubtful if this is really the case (Gower are smaller than those of the facial nucleus.

Upper portion of the fourth ventricle.—The floor boundary of the upper portion of the fourth ventricle, close above nuclei are for the most part situated, is marked in t each lateral half by a distinct somewhat angular depression

Fig. 275.

Fig. 275.—Anterior boundary (floor) of the fou (E.A.S.). Natural size.

m.s., median sulcus; *str.*, striæ acusticæ, mai between the upper part of the ventricle and the low part, calamus scriptorius; *l.r.*, lateral recess; *i.f.*, terior) fovea; *a.c.*, ala cinerea; *t.a.*, acoustic superior (anterior) fovea, close to the lateral margin part of the ventrtcle.

the inferior fovea, from which it is separated nence over which the striæ acusticæ pass. sion is termed the *superior fovea* (*s.f*). Bet the median sulcus is the prolongation of the eminentia teres, which is prominent opposi but becomes gradually less so above and below. Extending fr rior fovea to the upper end of the ventricle, where this na Sylvian aqueduct, is a shallow depression distinguished in t its dark grey or slaty tint, which is due to a subjacent t mented nerve-cells (*substantia ferruginea*). It is known *cæruleus*.

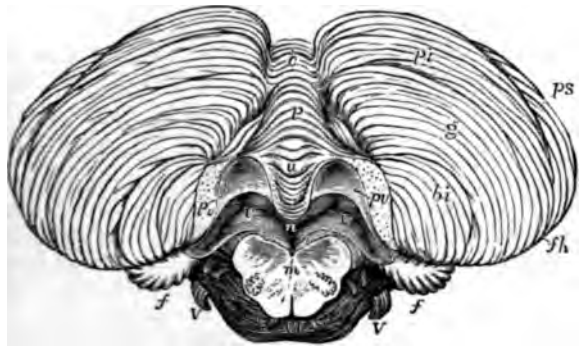
The lateral boundaries of this part of the ventricle are fo superior peduncles of the cerebellum (fig. 274, *s.c.p.*, fig. 282 pass gradually to the roof of the ventricle as they extend f upwards. They are at first separated from one another by wide interval which, however, gradually narrows near the ventricle, the two crura of opposite sides there approaching and their margins coming in contact. The triangular inte the two crura is bridged over by a lamina of white ma across with grey streaks. This is the *superior* (anterior *velum* or *valve of Vieussens* (fig. 274, *v.m.a.* in transverse s with the crura, forms the posterior boundary of the upper fourth ventricle. The white substance of which it is main is marked superficially by three or four flat transverse grey l intervening sulci, which together constitute the so-called *ling* *lng*). This is continued laterally and posteriorly into the

erebellum, while the subjacent white substance of the velum is in ontinuity with the central white matter of the cerebellum, into a pointed tent-shaped projection of the roof of the ventricle (fig. 279, *V4*, in longitudinal section). This projection is l below by the *inferior* (posterior) *medullary velum*, which in nner is prolonged from the white substance of the central part erebellum. It is less easily displayed than the superior velum, oncealed by a part of the cerebellum, which is attached to its r posterior surface. It will be further noticed in the description erebellum.

THE CEREBELLUM.

erebellum or hinder brain (fig. 276) consists of two lateral *hemi-* joined together by a median portion called, from the peculiar ap- e caused by the transverse furrows or ridges upon it, the *worm iform process*. This is seen on the under surface in the fossa n the hemispheres as a well-marked projection, named the *inferior rm process*, but above forms only a slight elevation, the *superior rm process* (fig. 277, *sv*). In birds, and in animals lower in the his middle part of the cerebellum alone exists, and in mammals it first part to be developed ; moreover, in most mammals it forms al lobe very distinct from the lateral portions.

Fig. 276.



.—LOWER SURFACE OF THE CEREBELLUM WITH THE INFERIOR (POSTERIOR) ILLARY VELUM (Allen Thomson after Reil and Reichert, and from nature). ⅔

edulla oblongata is cut across near the pons Varolii ; and the latter has been l somewhat from the cerebellum in order to bring into view the posterior y velum. To display this better the amygdalæ have been removed.
nterior superior lobe ; *f h*, horizontal fissure ; *p i*, posterior inferior lobe ; r lobe ; *b i*, biventral lobe ; *c* to *n*, inferior vermiform process, on which are, valvulæ, *p*, pyramid, *u*, uvula, *n*, nodule (the letter is placed in the fourth) ; *f*, flocculus ; *p v*, on each side, placed on the cut surface where the amygdalæ n removed, points by a line to the lateral part of the inferior medullary velum ; n part is continuous with the anterior surface of the nodule ; *v*, *v*, cavity of the ntricle ; the cavity extends on each side into the lateral recess ; *m*, medulla ; V, VI, roots of the fifth and sixth cranial nerves.

hemispheres are separated behind by a deep notch. The upper rm process, though slightly elevated, is not marked off from the

hemispheres, so that the upper surface of the organ, which is s
flattened in the middle and sloping downward on each side, is
rupted. Below, the hemispheres are convex, and are separated
fossa, named the *vallecula*, which is continuous with the notch
and in it the inferior vermiform process (fig. 276, *c* to *n*, fig. 27
lies concealed in a great measure by the surrounding parts
this hollow the medulla oblongata is received in front, and
cerebelli behind.

Fig. 277.

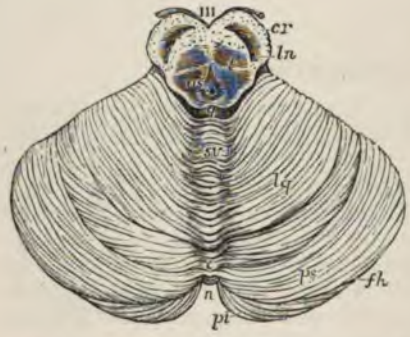


Fig. 277.—Outline of the
surface of the cere
(Allen Thomson.) ½

At the upper part of the
the crura cerebri and parts
them have been cut through
in connection with the cerebe
III, the third pair of nerv
upon the crura cerebri; *c*
matter or crust of the crura
l n, locus niger; *t*, tegmen
taining grey matter in the
part of the crura; *a s*,
Sylvius; *q*, corpora quadri
the letter is placed on the
lobe of the cerebellum; *s v*,
vermiform process; *l q* is
the anterior crescentic lobe,
with the sickle-shaped posterior crescentic lobe immediately below, forms the
superior or quadrate lobe; *p s*, postero-superior lobe; *f h*, horizontal fissure;
postero-inferior lobe; *n*, the notch between the hemispheres.

The greatest diameter of the organ is transverse, and extends to
three and a half or four inches: its width from before backwards
about two or two and a half inches; and its greatest depth is about
inches, but it thins out towards its lateral border.

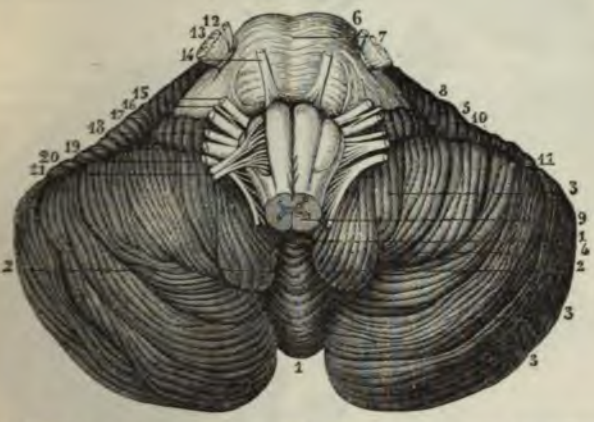
Lobes.—The cerebellum is characterised by its laminated or folia
appearance, its surface being everywhere marked by deep, closely set, tra
verse and somewhat curved, fissures, which extend a considerable dep
into its substance, but do not all entirely encircle the organ, for many
them coalesce with one another, and some of the smaller furrows
even an oblique course between the others. Moreover, on opening
larger fissures, many folia are seen to lie concealed within them,
reaching the surface of the cerebellum. Some of these fissures are bet
marked than others, the most conspicuous being the *great horizon
fissure* (figs. 276, 277, *fh*), which beginning in front at the midd
peduncle, extends round the outer and posterior border of each hemi-
sphere, dipping down into the posterior notch to unite with its fellow
the middle line. This fissure divides the cerebellum into an upper
lower portion, corresponding in fact to the upper and lower surfaces,
each of which several lobes, separated by fissures for the most pa
deeper than the rest, are described as follows:—

1. On the upper surface of the cerebellum. The *central lobe*, (fig. 277, *
consists of about eight folia, immediately adjoining the anterior con-
cave border; it is overlapped and partly concealed by the next lobe. Its
central part is continued upwards on to the superior medullary velum, in
the form of three or four shallow transverse laminæ, which together con-
stitute a structure which is termed from its shape the *lingula* (fig. 263,

The *antero-superior lobe*, sometimes called *quadrate*, and the *superior lobe*, are placed between the central lobe and the great tal fissure. The quadrate lobe has a comparatively narrow part off from it posteriorly which is sometimes distinguished as the *r crescentic lobe*, the rest of the quadrate being then designated *erior crescentic lobe* (see description of fig. 277). These lobes and ervening fissures, are all prolonged on to the superior vermiform , where they are less marked than on the hemispheres. More- he laminæ on that become reduced in number, the posterior r lobe being, indeed, represented on the worm only by a single arked lamina, the so-called *folium cacuminis* (fig. 277, below *c*).

n the under surface of the cerebellum. a. On the lateral hemi- s. From behind forwards are enumerated the *posterior inferior* ig. 276, *pi*), the *slender lobe* (*g*), the *biventral lobe* (*bi*), the *ala* (fig. 278, 4) and the *flocculus* (fig. 276, *f*). The first three considerable extent; the amygdala is a small rounded lobule, pro- into the vallecula, and abutting against the inferior vermiform , and the flocculus is a still smaller lobule which is partly con- by the biventral lobe, between which and the middle peduncle it s in the form of a fluted projection attached by a slender pedicle, is traceable mesially into the edge of the inferior medullary velum low).

Fig. 278.



78.—Inferior surface of the cerebellum with the pons Varolii and medulla oblongata (from Sappey after Hirschfeld and Leveillé). $\frac{2}{3}$

laced in the notch between the cerebellar hemispheres, is below the inferior vermi- rocess; 2, 2, median depression or vallecula; 3, 3, 3, the biventral, slender, and -inferior lobules of the hemisphere; 4, the amygdala; 5, flocculus or sub- ular lobule; 6, pons Varolii; 7, its median groove; 8, middle peduncle of the lmn; 9, medulla oblongata; 10, 11, anterior part of the great horizontal fissure; , smaller and larger roots of the fifth pair of nerves; 14, sixth pair; 15, facial 16, pars intermedia; 17, auditory nerve; 18, glosso-pharyngeal; 19, pneumo- ; 20, spinal accessory; 21, hypoglossal nerve.

On the inferior vermiform process. Situated most posteriorly is *ber valvulæ* (fig. 276, *c*), consisting of a few folia which unite the o-inferior, and slender lobes of the two sides. In front of this is a l projection named the *pyramid* (*p*), connected laterally with the

biventral lobes. Next is another smaller projection, the uvula, which is placed between the amygdalæ (removed at *p v*); these two having been suggested by a comparison with the parts so named in the throat. The connecting ridge of grey matter between the uvula and amygdalæ on each side, but concealed from view, is named the *furrowed band*. The pointed termination of the inferior vermiform process is named the *nodule* (fig. 276, above *n*), and corresponds with the flocculi at the sides. On each side of the nodule is the lateral part of the *inferior* (posterior) *medullary velum* (*p v*), appearing as a thin lamella of a semilunar form, which is continuous by its superior concave border with the central white substance of the worm, while the inferior concave border is free, or at least continuous only with the thin epithelial covering which forms the hinder boundary (roof) of the lower part of the fourth ventricle, covering the pia mater and its choroid plexus. The outer ends of these lateral lamellæ are attached to the flocculi.

Fig. 279.

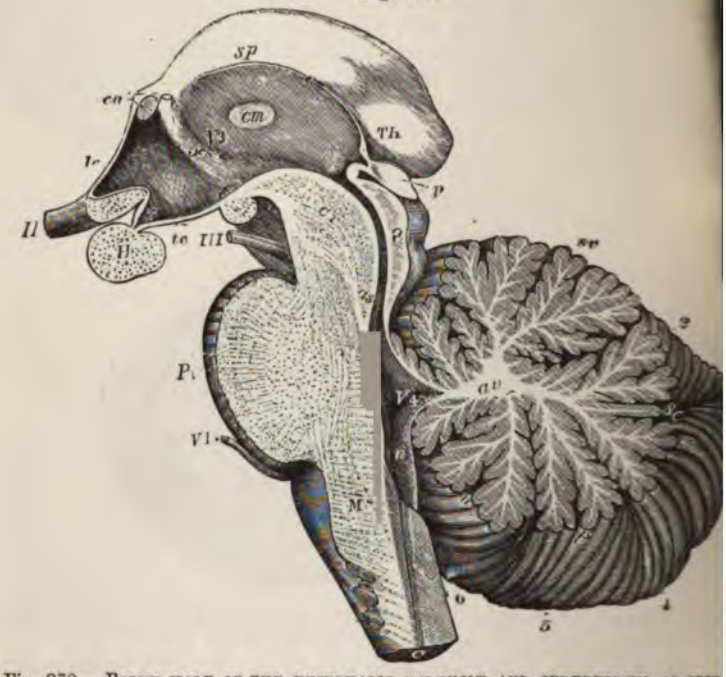


Fig. 279.—RIGHT HALF OF THE ENCEPHALIC PEDUNCLE AND CEREBELLUM AS SEEN FROM THE INSIDE OF A MEDIAN SECTION (Allen Thomson after Reichert).

The following letters refer to parts in connection with the medulla, pons, and cerebellum; PV, pons Varolii divided in the middle; M, medulla oblongata; *c*, central canal, divided longitudinally, with grey substance surrounding it; V4, middle of the fourth ventricle. In the cerebellum, *a v*, stem of white substance in the middle of the middle lobe of the cerebellum, ramifying into the arbor vitæ; *s v*, superior vermiform process or upper portion of the middle lobe; *s c*, single folium (lobulus cacuminis), which passes across between the postero-superior lobes; *c'*, the tuber valvulæ; *p*, pyramid; *u*, uvula; *n*, nodule; 1 to 2, laminæ of the antero-superior lobe; between V4 and 1 are seen the lingula and central lobe in section; 3, postero-inferior lobe or lobulus gracilis; 5, biventral lobe; 6, amygdaloid lobe.

ıds to the anterior surface of the nodule, and to each other just projection. The posterior velum thus constituted is covered ealed by the amygdalæ, and cannot be seen until those lobules ırned aside or removed as shown in the figure (fig. 276).

l structure of the cerebellum; arrangement of the white matter.—The central part both of the worm and s is composed of white substance, which sends out divergent lly thinning layers into the interior of all the laminæ, larger , the grey substance forming everywhere a continuous cover- r surface (fig. 280). In consequence of this arrangement of ınd grey substances, sections of the cerebellum crossing the sent a beautifully foliated or arborescent appearance, named (*a v*, fig. 279). This appearance is seen in any vertical it is most perfect in that which passes through the median e the relative quantity of the central white matter is small. ons are arranged somewhat pinnately, the section of each ına having those of secondary laminæ clustered round it like stalk.

n branches of the white medullary substance, or groups of spond with the lobules above enumerated, as indicated in the . 279 and 280).

teral hemispheres, with which the peduncles are connected, ıatter is more abundant than in the worm (fig. 280); and, if

Fig. 280.

SECTION ONE OF SPHERES BELLUM, HE ME- CENTRE OLONGA- O THE AMELLÆ

ıte nu- edullary hemi- he latter primary inæ. Of s to the

the biventral lobule, *3* and *4* to the postero-inferior lobule, *5* to the pos- obule, *6* to *12* to the antero-superior lobule, and *13* to the lateral part of ule. *a*, one or two small laminæ at the bottom of the great horizontal fis- e between the two parts of the quadrate lobule; *f*, stalk of the flocculus.

made through either hemisphere half way between its centre ldle of the vermiform process, it will display a nucleus of grey ch is named the **corpus dentatum** of the cerebellum (*n d*). ıre, very similar to that already described in the olivary body ulla oblongata, presents the appearance of a waved line of llowish brown substance, containing white matter within. interrupted at its upper inner part. In whatever direction is carried through the corpus dentatum, the outline has the character, so that the dentate nucleus may be described as f a plicated pouch or capsule of grey substance open at one

part and inclosing white matter in its interior, like the nucleus of the olivary body. The fibres which issue from it may be tra superior peduncles of the cerebellum and to the valve of Vieus

In addition to the corpus dentatum certain other portions of grey m have been only more recently recognised, are found in the white c cerebellum (Stilling). They are three in number on each side and respectively the nucleus emboliformis, nucleus globosus, and nucleus f *nucleus emboliformis* (fig. 281, *x*) is a small clavate mass of grey sub mesially to and partly covering the hilus of the dentate nucleus. side of the nucleus emboliformis, and at a somewhat lower level, i grey matter passing antero-posteriorly and ending behind in an e tremity. This has been named the *nucleus globosus* (*y*). Finally, close t line, where it is only separated from its fellow by a narrow septu matter, is a rather larger portion of grey substance, which lies in part of the white centre of the worm, and close to the upper wall like projection in the roof of the 4th ventricle. It is termed *fastigii* (*z*). These several portions of grey matter are not entirely isol connected here and there both with one another and with the dentate

Fig. 281.

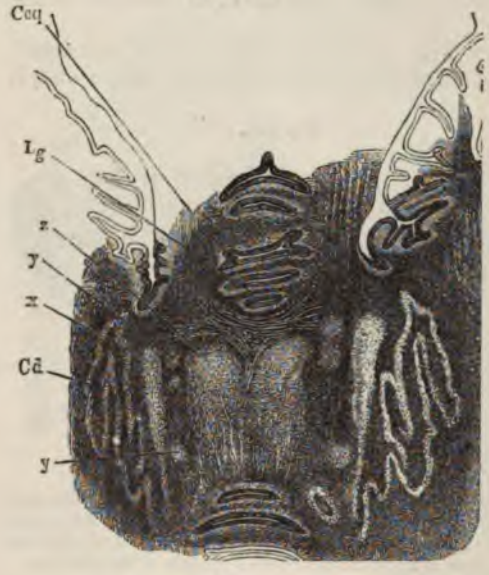


Fig. 281.—HOR TION THROUGH CENTRE OF THE SHOWING THE GREY MATTER after Stilling.

The section is over the roof o ventricle. The presented lighte white matter in are embedded.

C d, corpus d nucleus embolifo nucleus globosus fastigii. Above lesced roof-nucl some of the fi superior (anteri tion, and above the laminæ and f lingula (L g); the roof-nuclei laminæ and fur inferior vermifor included in the s superior cerebella

The **cereb duncles** are constituted by white fibres which pass out fr the white medullary substance of the hemispheres.

The *superior peduncles* (crura ad cerebrum) emerge from the of the medullary substance of the hemispheres, and run up forwards towards the base of the corpora quadrigemina, un they disappear. They are situated at first more at the side, quently in the roof, of the upper part of the fourth ventric peduncles are concealed by the anterior part of the cerebellu to see them properly this must be divided in the middle turned aside. When this is done the superior crura, with th

rior) medullary velum stretched out between them, are brought to

he *middle peduncles* (crura ad pontem) constitute the commissure of erebellar hemispheres. They emerge from the lateral part of the e substance of the hemisphere, and pass forwards to become the sverse fibres of the ventral half of the pons.

he *inferior peduncles* (crura ad medullam) issue from the white ter of the lateral hemispheres, between the other two, and pass vards immediately outside the superior peduncles to reach the lateral l of the fourth ventricle. Here they turn sharply downwards, at a t angle, and become the restiform bodies of the medulla oblongata.

Fig. 282.

282.—FIGURE SHOWING HE THREE PAIRS OF CERE-ELLAR PEDUNCLES (from appey after Hirschfeld and eveillé).

n the left side the three ebellar peduncles have been short; on the right side hemisphere has been cut iquely to show its connection h the superior and inferior duncles.

1, median groove of the arth ventricle; 2, the same ove at the place where the ditory striæ emerge from it cross the floor of the ntricle; 3, inferior peduncle restiform body; 4, funi-lus gracilis; 5, superior duncle; on the right side e dissection shows the perior and inferior peduncles ossing each other as they into the white centre of the cerebellum; 6, fillet at the side of the crura cerebri; , lateral grooves of the crura cerebri; 8, corpora quadrigemina.

MINUTE STRUCTURE OF THE CEREBELLUM.

The **cortical grey substance** is composed of two distinct layers, viz.:—an outer clear grey layer, and an inner greyish-red "granule" layer. At the junction of the two is an incomplete layer of large cells, termed the corpuscles of Purkinje. Outside all is the pia mater, from which vascular processes extend inwards into the nervous substance.

The *outer layer* (fig. 283, *b*) consists of a delicate matrix, apparently of the nature of neuroglia, containing cells and fibres. Most of the fibres have a direction at right angles to the surface; the greater number of them are the processes of the large nerve-cells which lie between the two layers. Others are fine tapering fibres, analogous to the sustentacular fibres of the retina, and abutting by a broad base against the inner surface of the pia-mater. The cells of this outer layer are granule-like bodies, some very small, and belonging probably to the matrix, others somewhat larger and probably nervous, with processes extending from one or more sides. Some of the corpuscles are connected with the processes of the large cells of Purkinje (see fig. 284). The inner part of this layer, contiguous

with the corpuscles of Purkinje, contains nerve-fibres running p to the surface.

The *inner* or *granule layer* (fig. 283, *d*), next the medullary consists of granule-like corpuscles embedded as close groups in tinous matrix, which contains also a plexus of fine nerve-fibres.

Fig. 283.

Fig. 284.

Fig. 284.—PROCESSES OF THE OF PURKINJE, CONNECTED, FINER BRANCHES, WITH COR THE OUTER LAYER OF THE CORTEX (Sankey). Highly m

a, *a*, processes of the corpus kinje ; *b*, a branch from one of t is connected with two of the c the outer layer *c*, *c*, scattere corpuscles of this layer.

Fig 283.—STRUCTURE OF CORTEX OF CEREBELLUM (Sankey).

a, pia mater ; *b*, external layer ; *c*, layer of corpuscles of Purkinje ; *d*, inner layer ; *e*, medullary centre.

corpuscles vary in size from $\frac{1}{4000}$th to $\frac{1}{2500}$th of an inch, th being less densely scattered around the corpuscles of Purkinje. are round, others angular. Each cell is formed of a nucleus wit protoplasmic envelope, the processes from which are supposed to nected with the plexiform nerve-fibres among which the cells lie.

The *cells of Purkinje* (fig. 283, *c*) lie between the outer an

of the grey cortex. They are more closely set at the margins of minæ than elsewhere. Some are irregular in form, but most are haped, their long axis being at right angles to the surface. The ter of the larger cells is $\frac{1}{800}$th to $\frac{1}{1000}$th of an inch. Processes d from them into both the outer and inner layers: the outer pro- being much the larger. It usually divides close to the cell, and its ches, either at once or after a short horizontal course, pass towards surface, dividing repeatedly. Some are connected with the corpuscles e outer layer (fig. 284), but most can be traced nearly to the outer ce, and are there lost. The inner process is fine, undivided, and s into the granule layer, where it is continuous with the axis- der of a nerve-fibre.

e **medullary or white centre** of each lamina, consists of nerve- s arranged in parallel or interlacing bundles, which pass from the al white matter of the worm or of the hemispheres, and appear to obliquely into the cortical grey substance. They disappear in the ule layer, and are believed to be continuous with the axis-cylinder esses of the corpuscles of Purkinje, but some are of opinion that they , in part at least, by the union of the fine fibres of a plexus in the r layer.

e structure of the *corpus dentatum* resembles that of the olivary body. ste cells $\frac{1}{1500}$th to $\frac{1}{3500}$th inch in size, lie in grey matter which is traversed ndles of nerve fibres, passing in various directions but chiefly from without rds.

e *nucleus emboliformis* agrees closely in structure with the nucleus dentatus, hich it seems to bear the same relation as do the accessory olivary nuclei he chief olivary nucleus. The *nucleus fastigii* and *nucleus globosus* differ what in structure from the dentate nucleus, and chiefly in the much larger of their cells, which, according to Meynert, are very similar to those of the lled outer auditory nucleus or nucleus of Deiters in the pons (see p. 303).

ourse of the fibres in the central white substance of the ebellum.—Tracing the fibres of the cerebellar peduncles into the te centre of the organ, it is found that their general arrangement and ribution is as follows :—Those of the *middle peduncles* coming from pons Varolii enter the lateral part of the white matter in two main dles. One of these, composed of the superior transverse fibres of pons which pass obliquely downwards over the others, radiates o the lateral and ventral parts of the medullary centre of the hemi- eres (fig. 285, m^*). The other bundle, which is formed of the lower nsverse fibres of the pons, is joined at its passage into the white centre the *restiform body* or *inferior peduncle* (fig. 285, *n*), and the fibres both, blending in their further progress, turn upwards and radiate the upper parts of the medullary centre of the hemispheres, and the upper part of the worm. Those which pass into the worm ve over the corpus dentatum, and are termed by Stilling the semi- ular fibres. A small part of the fibres of the restiform body is by Stilling to enter the corpus dentatum. The *superior peduncle* es almost entirely into the interior of the dentate nucleus, but some s curve round the outer side of this without passing into it, while e of the mesial fibres are traceable directly into the white substance he worm. Probably many of the fibres of these peduncles which r the dentate nucleus are connected with its cells, but others pass

narrows, and which in front expands abruptly into the third It is rather more than half an inch long. In shape it varies in rts, being T-shaped in section below (near the fourth ventricle) above (near the third), and in the intermediate part of an oval form, but somewhat shield-shaped in the region of the rpora quadrigemina. It is lined by ciliated columnar epi- utside which is a thick layer of grey matter, continuous with e fourth ventricle. Outside this *grey matter of the aqueduct*, and ventral parts (basal part) of the mesencephalon are com- ne thick masses of the *crura cerebri*, whilst the roof or pos- is formed by the *lamina quadrigemina*, so called from bearing amillated tubercles known as the corpora quadrigemina.

y matter of the aqueduct is a layer of some thickness (2 to ers) which surrounds the aqueduct, and is prolonged from the r of the fourth ventricle. It is characterised by the large vessels which are distributed in it. It contains, scattered s substance, nerve-cells of varying size, the largest being forwards from the locus cœruleus of the fourth ventricle; are very numerous and small at the dorsal side of the In addition to these scattered cells the grey matter of the contains certain more defined groups or columns of cells connected with the roots of the third, fourth, and fifth ves.

cleus of the third and fourth nerves extends on either almost the whole length of the ventral part of the aqueduct, he middle line, the nuclei of the two sides being only from one another by the raphé; superiorly they even meet . The cells of this nucleus are very large and irregular in

er nucleus of the fifth nerve consists of a comparatively ber of large globose cells, which lie at the extreme lateral the grey matter of the aqueduct close to the bundles of the root of the fifth nerve, towards which their axis-cylinder re directed.

VENTRAL PART OF THE MESENCEPHALON: CRURA CEREBRI.

ra cerebri (fig. 260, *P*) emerge from the upper border of the liverge from one another, leaving between them the posterior space and the corpora mammillaria and disappearing in the mispheres under the optic tract. Near the point of the angle ce the roots of the third nerves issue in several bundles from long their inner side; and this groove serves to indicate the between the more prominent ventral part of the peduncle *s s. crusta pedunculi*) and the dorsal and larger part (*tegmentum*) great measure concealed from view by the pes when viewed and in front, only appearing as a small tract on either side erior perforated space. A section into the crus cerebri shows rts of which it is composed to be separated from one another ; of dark coloured grey substance known as the *substantia* h comes to the surface on the inner side at the groove above from which the third nerve issues (sulcus oculomotorii), and er side also along a grooved line—the lateral sulcus.

Of the two main parts of each peduncle the *crusta* is fo
almost entirely of longitudinal bundles of fibres which are conti
with the pyramid-fibres of the medulla oblongata and pons,
others being superadded, whilst the *tegmentum* is a continuation
the formatio reticularis of those parts, with the addition of much
matter and white fibres, amongst the latter being those of the sup

Fig. 286.

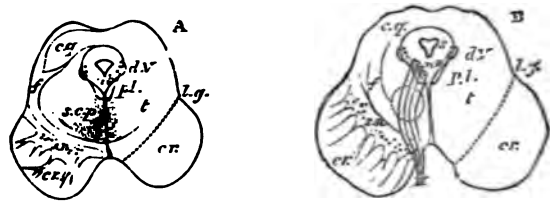


Fig. 286.—Outline of two sections across the mesencephalon. Natural
(E. A. S. After Stilling.)

A, through the middle of the inferior corpora quadrigemina; B, through the
of the superior corpora quadrigemina.

cr, crusta; *s n*, substantia nigra; *t*, tegmentum; *s*, Sylvian aqueduct, with
surrounding grey matter; *c.q*, grey matter of the corpora quadrigemina; *l.g*,
groove; *p.l*, posterior longitudinal bundle; *d. V*, descending root of the fifth nerv
s.c.p, superior cerebellar peduncle; *f*, fillet. The dotted circle in B indicates the
tion of the tegmental nucleus.

peduncle of the cerebellum. The two ventral portions (crustæ or pedes) are entirely distinct from one another (as shown in the accompanying sections, fig. 286), and each is marked off externally from the tegmentum of the same side by the grooves just mentioned; but the two tegmenta are closely united in the middle line by a prolongation of the raphé, and extend dorsally at the sides of the aqueduct to become continuous with the bases of the corpora quadrigemina.

Crusta, pes or basis of the crus cerebri: proper cerebral peduncle. The crusta is semilunar in section, the substantia nigra projecting into it with a convex border. It is wholly made up of longitudinal white fibres which are arranged in flattened bundles, with their edges in and out, separated from one another by processes of pia mater. The main part is a direct prolongation of the pyramid-bundles of the pons and passes superiorly towards the internal capsule of the cerebral hemisphere.

Close to the substantia nigra, the bundles of white fibres are smaller and somewhat separated by projections of the grey matter extending between them. These have both a different origin and a different destination from the other fibres of the crusta: for on the one hand they are traceable from the formatio reticularis of the medulla and pons, and on the other hand they for the most part terminate in the cells of the substantia nigra, although some of them pass on to the lenticular nucleus of the corpus striatum (Meynert). They have received the name of *stratum intermedium*. Further, according to Meynert, the outer or lateral bundles of the crusta have also an origin and destination different from the main tract. He states that they are traceable from the posterior columns of the spinal cord and lower part of the medulla, crossing over to the opposite side just above the decussation of the lateral pyramidal tract (upper pyramidal decussation, fig. 267, *s. p. d.*) and then passing up with this through the medulla, pons, and crura

[illegible] to spread out directly in the posterior lobes of the cerebrum without [illegible]ming connected with any of the ganglionic masses at the base of the [illegible]ispheres. Lastly the mesially situated bundles of the crusta appear also to be [illegible]tinct from the pyramidal tract proper (Flechsig), being developed at a some[illegible]t later period. Thus there have been traced at least four different sets of [illegible]es in the crusta, and a fifth set may perhaps be added to include fibres derived [illegible]ginally from the cerebellum and joining the pyramidal tract in its passage [illegible]rough the pons, such fibres being probably scattered amongst the fibres of the [illegible]ther tracts.

It is remarkable that whereas in the lower part of its course (spinal cord and [illegible]edulla) the fibres of the pyramidal tract acquire a medullary sheath later than [illegible]e other fibres of the white columns, in the upper part (crus cerebri and cerebrum) [illegible] is acquired earlier than in the other fibres.

The **substantia nigra** is a mass of grey matter which is characterised [illegible]by the presence of a number of very darkly pigmented irregular nerve-[illegible]cells, which give the substance on which they are scattered the appear[illegible]ance from which it derives its name. It forms a layer which separates [illegible]he basis or crusta from the tegmentum. It is thicker near the mesial [illegible]border of the peduncle than laterally, where the tract of the fillet may [illegible]be but incompletely separated from the longitudinal bundles of the [illegible]crusta. It commences at the upper margin of the pons, and can be [illegible]traced as far forwards as the posterior border of the corpora albicantia. [illegible]At the origin of the third nerve it is traversed in its mesial part by the [illegible]fibres of the nerve-root. The grey matter of the substantia nigra pro[illegible]jects here and there between the adjacent bundles of the crusta; one [illegible]considerable projection in particular in the posterior part of the mesen[illegible]cephalon serving to mark off the mesial portion of the crusta from the [illegible]rest.

The cells in this projection are much smaller, and relatively more numerous than in the rest of the substantia nigra.

The **tegmentum**, like the formatio reticularis of the medulla and pons, of which it is the prolongation upwards, is composed of small longitudinal bundles of white fibres, separated by transversely coursing or arched fibres, together with a considerable amount of grey matter containing scattered nerve-cells. Many of the longitudinal fibres are probably continued from the anterior columns of the cord, and above they may be traced into the optic thalami.

In addition to these diffused bundles of longitudinal fibres there are some others which are collected into more defined tracts. One such tract constitutes the *posterior longitudinal bundle*, which is seen in all sections of this part of the brain as a pyriform area of transversely cut fibres which lies on each side of the middle line between the grey matter underlying the aqueduct, and the formatio reticularis (fig. 286, *p.l*). The fibres which constitute this bundle below have already been noticed (see p. 298 and fig. 274); traced upwards the bundle disappears near the posterior commissure, either by its fibres becoming dispersed in the rest of the formatio reticularis, or by their having become united with the nerve-nuclei (3rd and 4th) in the mesencephalon.

Another tract of longitudinal and decussating fibres is derived from the superior peduncle of the cerebellum, which we have already traced as it passes forwards over the anterior end of the fourth ventricle. Reaching the sides of the aqueduct as a well-marked bundle, of semilunar shape in section (fig. 274, *s.c.p*), it gradually takes a lower position as it is traced upwards in the mesencephalon, and its fibres soon begin to pass across the raphé, decussating with those of the other side (fig. 286, A), the decussation extending as far forwards as the superior

pair of corpora quadrigemina. Having thus entirely crossed to the opposite side the tract in question pursues its course longitudinally upwards, enclosing in its passage a tract of grey matter with numerous large pigmented cells, known as the *nucleus of the tegmentum* or *red nucleus* (fig. 286, B, and fig. 288), probably receiving an accession of fibres from these cells. Above, the tract passes into the ventral part of the optic thalamus.

Lastly, in sections across the upper part of the pons a considerable fasciculated bundle of longitudinal fibres (tract of the fillet, fig. 274, *l*) begins to make its appearance at the ventral border of the formatio reticularis, and is traceable upwards into the same part of the tegmentum. Soon, however, the longitudinal fibres of this tract are seen to pass obliquely outwards and emerge at the side of the crus cerebri, curving obliquely over the outer side of the prolongation of the cerebellar peduncle (fig. 286, A, *f*), and tending for the most part towards the inferior corpora quadrigemina. They are seen on the surface as a tract of obliquely curved fibres known as the *fillet* (lemniscus) occupying a triangular area at the side of the tegmentum (fig. 287, *f*). They are reinforced by fibres from the anterior medullary velum which also curve round the superior cerebellar peduncle. The fillet is covered externally by a thin layer of grey matter containing nerve-cells.

All the fibres of the tract of the fillet do not, however, take the course above indicated. Those nearest the middle line (inner portion, fig. 274, *l*) are said by Meynert to pass upwards in the stratum intermedium of the crusta. Those next in order (middle portion) according to Forel are for the most part continued upwards in the formatio reticularis of the tegmentum, but (with the exception of a small part which runs to the corpus albicans) become lost amongst its longitudinal bundles and are no longer traceable as a distinct tract. Some of the lateral fibres of this middle portion, however, pass to the upper corpora quadrigemina (fig. 286, B, *f*). It is especially the lateral portion of the tract of the fillet which passes to the side and enters the lower corpora quadrigemina. This is sometimes distinguished as the *lower fillet* from the tract which enters the upper quadrigeminal bodies (*upper fillet*). Traced downwards the fibres of the fillet pass into the posterior part of the lateral column of the medulla oblongata, and also, according to Roller, into the anterior column.

The *arcuate fibres* of the formatio reticularis of the tegmentum include besides the decussating fibres of the cerebellar peduncles, and the curved fibres of the fillet, others the origin and destination of which are but imperfectly understood. Some are said to be derived from the cells of the nucleus of the tegmentum before mentioned, and others from certain large spheroidal nerve-cells in the lateral part of the grey matter of the aqueduct (upper nucleus of the 5th nerve).

Dorsal part of the mesencephalon: corpora quadrigemina. As before stated the Sylvian aqueduct is covered on its dorsal aspect by the quadrigeminal lamina, bearing the bodies of the same name. The mesial part of the lamina is marked by a comparatively wide groove, shallower inferiorly, which serves to separate the corpora quadrigemina of opposite sides (fig. 282). This grooved surface, which is raised above the level of the upper medullary velum immediately behind, is connected with the velum by a small median strand of longitudinal fibres termed the *frenulum veli* (fig. 287, *fr*). In front of the upper (anterior) pair of corpora quadrigemina the groove is interrupted by a transverse white prominence—the *posterior commissure;* but both this and the upper end of the median groove are in the natural condition concealed by the pineal body (*p*), which projects backwards and downwards from the posterior wall of the third ventricle and rests between the upper pair of quadrigeminal bodies. A well-marked narrow transverse groove which commences a short distance from the middle line and is curved round the lower border of the upper tubercle separates this from the lower tubercle of the same side

The **corpora** or **tubercula quadrigemina** are two pairs of rounded eminences which are mainly composed of grey matter, although covered

Fig. 287.

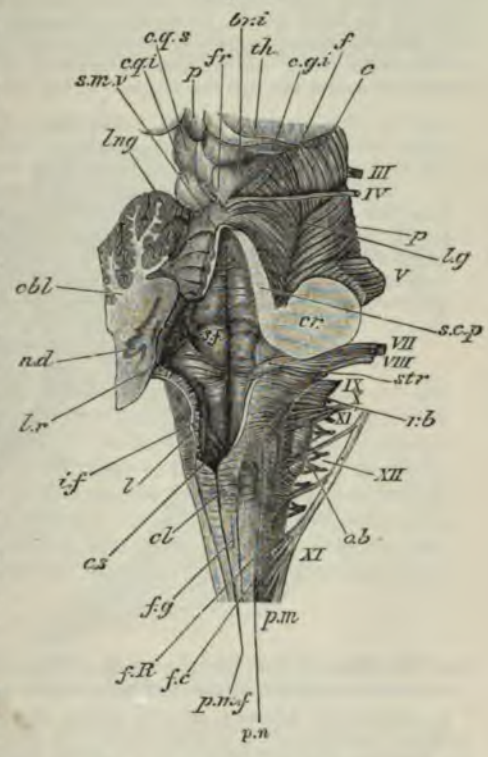


FIG. 287.—VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON FROM THE RIGHT SIDE AND BEHIND (E.A.S.)

The cerebellum, the inferior medullary velum, and the right half of the superior medullary velum, have been cut away, so as to display the fourth ventricle.

c.q.s, *c.q.i*, superior and inferior quadrigeminal bodies of the right side; the pineal gland, *p*, is seen projecting backwards between the superior bodies, and the frænulum, *f r*, passes up from the superior medullary velum, *s.m.v*, to the interval between the posterior quadrigeminal bodies; *th*, right thalamus opticus; *br.i*, brachium of the inferior quadrigeminal body passing underneath the inner geniculate body, *c.g.i.*; *l*, superficial stratum of fibres of the fillet, covering the tegmentum of the crus cerebri; *c*, crusta of the crus cerebri, separated from the tegmentum by the lateral groove, *l.g.*; *p*, upper part of the pons; III., IV., etc., the corresponding cranial nerves. The rest of this figure will be found described at p. 286.

externally with a thin layer of transverse white fibres. The upper or anterior tubercles (fig. 287, *c.q.s.*) are somewhat broader and darker in colour, but slightly less prominent than the lower or posterior (*c.q.i*). Laterally the corpora quadrigemina are not bounded by a groove but each appears to be prolonged obliquely upwards and forwards into a prominent white tract, known as the *brachium* of the corresponding tubercle. The lower (posterior) brachium (fig. 287, *br.i.*) loses itself underneath an oval prominence which is seen at the side of the upper end of the crus cerebri and is termed the *inner geniculate body* (fig. 287, *c.g.i.*; fig. 261, *i.*); from the opposite side of this, one of the roots of the optic tract passes. The upper (anterior) brachium passes between the same geniculate body, and the prominent posterior extremity of the optic thalamus with the external geniculate body (fig. 261, *Th*, *e*) directly into the optic tract, of one of the roots of which it may be regarded as a prolongation; but the continuity into this is much better seen in some animals than in man.

The **lower or posterior quadrigeminal bodies** are composed almost entirely of grey substance (the so-called *nucleus* of these bodies (fig. 286A, *c.q*)) which is separated by a thin layer of the fillet from the grey matter of the aqueduct and contains numerous small and some larger nerve-cells. The nuclei are united across the middle line by a commissural

portion of grey matter which is bounded superficially and deeply transverse white fibres derived from the fillet.

The superficial fibres are continuous laterally and in front with the fibres the brachium of the inferior quadrigeminal body, and laterally and behind w those of the lower fillet. According to Meynert the fibres of the lower fillet one side pass obliquely across the quadrigeminal bodies to emerge as the brachi on the other side: this continuity, however, if it really exists, is probably direct but occurs through the medium of the nerve-cells in the grey matter.

Fig. 288.

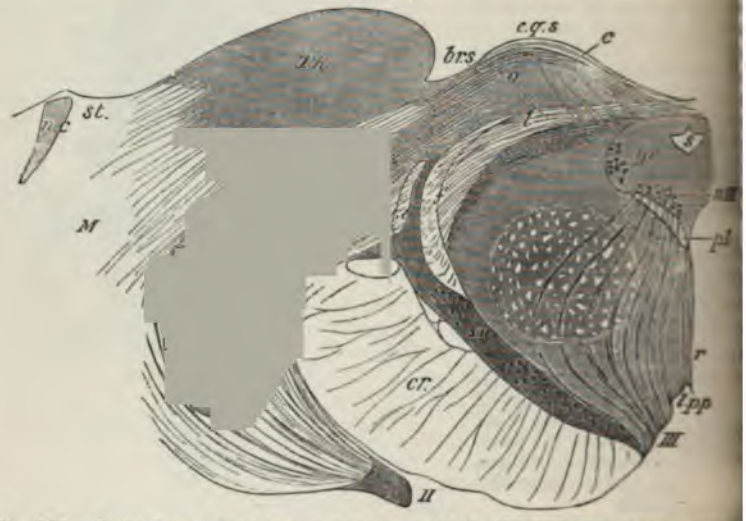


Fig. 288.—SECTION THROUGH THE SUPERIOR PART OF ONE OF THE SUPERIOR CORPORA QUADRIGEMINA AND THE ADJACENT PART OF THE OPTIC THALAMUS (after Meynert).

s, aqueduct of Sylvius; *gr*, grey matter of the aqueduct; *c.q.s*, quadrigeminal eminence, consisting of: *l*, stratum lemnisci; *o*, stratum opticum; *c*, stratum cinereum; *Th*, thalamus (pulvinar); *c.g.i*, *c.g.e*, internal and external geniculate bodies; *br.i*, superior and inferior brachia; *f*, fillet; *p.l*, posterior longitudinal bundle; *r*, raphé; III, third nerve; *n*. III. its nucleus; *l.p.p*, posterior perforated space; *s.n*, substantia nigra; above this is the tegmentum with its nucleus, the latter being indicated by the circular area; *cr*, crusta; II, optic tract; *M*, medullary centre of the hemisphere; *n.c*, nucleus caudatus; *st*, stria terminalis.

The **upper or anterior quadrigeminal bodies** are covered, like the lower, with a thin stratum of white fibres (*stratum zonale*). Within this is a cap-like layer of grey matter (*stratum cinereum*, fig. 288, *c*), containing numerous small nerve-cells, of considerable thickness at the most prominent part of the tubercle, but thinning off towards its margins. Within this, again, is the most characteristic part of the organ. This is a layer of longitudinally coursing bundles of fine nerve-fibres (*stratum opticum*, *o*), between which lie small scattered nerve-cells embedded in grey matter, which is continuous peripherally with that of the stratum cinereum. In front the nerve-fibres pass outwards and forwards into the upper brachium (*br. s*), and along this into the optic tract. Fine from the next layer pass vertically into this stratum. Lastly, betwe optic-fibre layer and the grey matter around the aqueduct is a well-marked layer composed of medullated fibres derived from the fillet (*stratum lemnisci*, *l*). This is thicker at the side, where the

, and becomes gradually thinner near the middle line, where many fibres pass across, decussating with fibres from the opposite side. radual thinning of the stratum appears to be due to the passage of res outwards into the optic-fibre layer; but some fibres (accord- Tartuferi, whose comparative investigations have thrown much upon the minute anatomy of this part) pass inwards towards the matter of the aqueduct.

stratum cinereum and stratum opticum of the upper quadrigeminal body together to correspond to the nucleus of the lower quadrigeminal body; atum zonale to the superficial white layer, and the stratum lemnisci to the white layer, which is also, as above mentioned, traceable to the fillet. connexion of the anterior quadrigeminal bodies with the optic tract and se of sight is far more intimate than that of the posterior. For if in a animal the eye on the one side be extirpated, the operation is found to be ed after some time by atrophy of the anterior quadrigeminal body and of chium, whereas the posterior quadrigeminal body and brachium is unaltered m). Moreover in the mole the posterior quadrigeminal body is well ped, whereas the anterior is atrophied.

e **posterior commissure**, which overlies the upper end of the duct and appears in the posterior wall of the third ventricle, is ally described with that cavity. It is, however, a direct continua- of the commissural fibres of the fillet above mentioned. Its fibres e from the tegmental part of the mesencephalon, and after crossing he other side appear to pass through the thalamus and diverge into white substance of the cerebral hemispheres. They may in part prise commissural fibres between the two thalami. Some are con- ted with the pineal body.

E THIRD VENTRICLE AND THE PARTS IN CONNEC- TION WITH IT: THALAMENCEPHALON.

The Sylvian aqueduct expands suddenly immediately after passing eath the posterior commissure into a comparatively large, laterally pressed cavity, termed the **third ventricle** (figs. 289, 290). This, ch is on the whole larger in front than behind, gradually narrows ts anterior end in a dorsal termination which lies over the optic missure. Below and behind this is a conical depression, leading ards the pituitary body. At the posterior extremity, immediately re the entrance of the aqueduct and separated from it by the posterior missure, is another smaller depression extending into the stalk of the al gland (fig. 290, *g*), which here, as we have seen, projects towards the mesencephalon. The ventricle is bounded laterally by the optic *zmi* (fig. 289, *Tm*), which come almost in contact with one another in middle line; and a little in front of the middle of the ventricle, actually united by a transverse band of grey matter of variable nt, termed the *massa intermedia*. This is sometimes ble, and occasionally wanting. It is believed to be connected with brain. The lateral walls of the cavity are slightly curved and ced towards the middle, and by a thin layer of white matter with exity forwards, which becomes much thicker towards the middle rds the roof. The roof is formed by the *tela choroidea* (fig. 290, *f*). Immediately behind this is the posterior part of of these, between it and the anterior part of the ventricle is the

aperture (*foramen of Monro*) leading into the ventricle of the h
(lateral ventricle). All along the upper curved margin of t
wall, from the pillar of the fornix to the pineal gland, run
stria, known as the *stria pinealis*, or *tænia fornicis* (fig.
fig. 289, *Tfo*). The floor of the ventricle is formed post
the *tegmenta* of the crura cerebri, and where the crura div
one another by the following parts, which have been alre
tioned as seen at the base of the cerebrum; viz., commen
behind, the *posterior perforated space*, the *corpora albicantia*,
cinereum and *infundibulum*, and the *lamina cinerea*, the last
also serves to close the ventricle in front. The roof of the
limited before and behind by two commissures, named f
position, anterior and posterior. Of these the anterior belo
description of the cerebral hemispheres, while the posterior h
been noticed in connection with the mesencephalon.

Fig. 289.

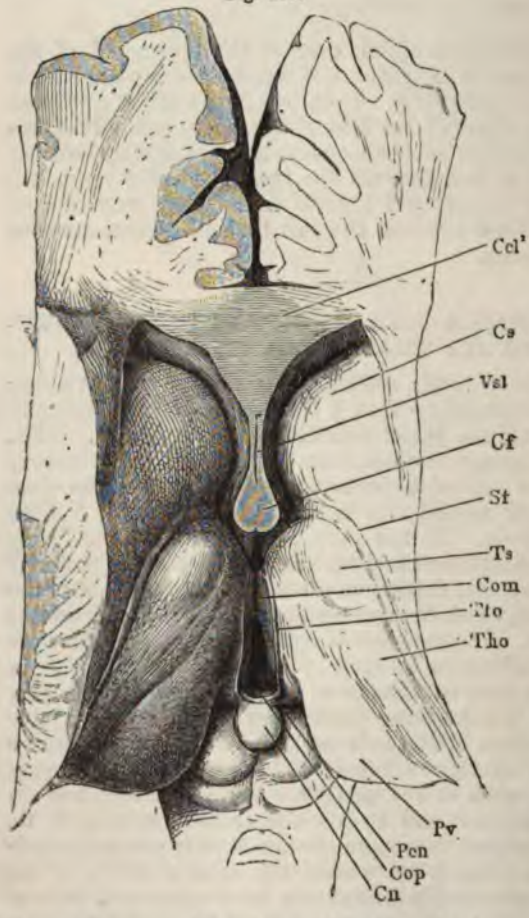


Fig. 289. —
ABOVE OF
VENTRICLE
OF THE LA
TRICLES (He

The brain ha
horizontally
below the corp
and the fornix
interpositum h
moved.

Tho, thalam
Ts, its anteric
Pv, pulvinar;
commissure str
tween the
thalami across
of the third ven
columns of the
pineal gland
downwards and
between the su
pora quadrigem
stria terminali
cleus caudatu
corpus striatu
ventricle of th
lucidum; *Ccl*²,
the genu of
callosum; *Pen*,
ment of the p
or peduncle,
posterior comm

The third
like the f
roofed over
epithelial l
the central
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not free bu
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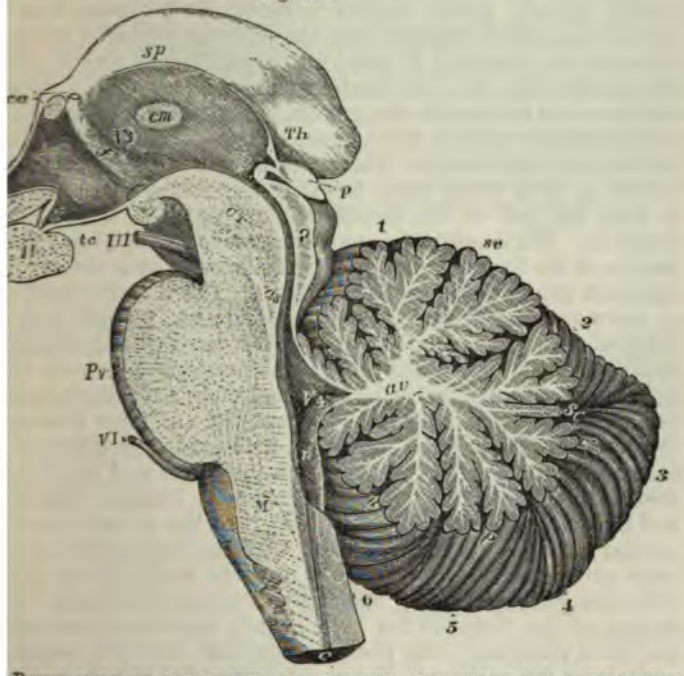
the median portion of an expansion of pia mater named th

um, which overlies the third ventricle as well as the larger he optic thalami. The epithelium follows all the inequalities inged vascular tracts (*choroid plexuses*) which project down- m the membrane; and, therefore, becomes torn away when nater is removed. At the white stria on either side it is is with the epithelium covering the lateral wall.

Fig. 290.



-RIGHT HALF OF THE ENCEPHALIC PEDUNCLE AND CEREBELLUM AS SEEN FROM THE INSIDE OF A MEDIAN SECTION (Allen Thomson after Reichert).

optic nerve; behind it the optic commissure divided; III, right third nerve; erve; V 3, third ventricle; *Th*, back part of the thalamus opticus; *H*, sec- pituitary body; *p*, pineal gland; below its stalk is the posterior commissure; r commissure divided, and behind it the divided anterior pillar of the fornix; cinerea; *i*, infundibulum (cavity); *t c*, tuber cinereum; behind it the corpus *f*, mark of the anterior pillar of the fornix descending in the wall of the third *c m*, commissura mollis; *s p*, stria pinealis or peduncle of pineal gland; quadrigemina; *a s*, aqueduct of Sylvius near the fourth ventricle; *cr*, crus V, pons Varolii; *M*, medulla oblongata; and behind these the cerebellum.

ird ventricle is lined like the other cavities already described by pithelium, which is thin and flattened over the roof, *i.e.* lining n and choroid plexuses, but longer and more columnar at the nd sides. The floor, which is narrow, is formed, underneath helium, of grey matter continuous with that of the Sylvian , and this grey matter extends a short distance upwards vall of the thalamus. The central grey substance behind rests still conjoined part of the tegmenta; but anteriorly, after these erged, it comes to the surface at the base of the brain as the perforated lamina and the tuber cinereum. The lateral walls of

the ventricle have but a thin covering of neuroglia (epend
neath the lining epithelium; so that the white covering of t
comes to view through it.

The **optic thalami** (fig. 289, *Tho*), as seen from
the removal of the fornix and velum interpositum, are som
shaped masses of grey substance covered superficially by a t
of white fibres. The upper surface is marked by a shi
tudinal groove, which inclines inwards as it passes for
terminates a short distance from the anterior extremity of
This anterior extremity is raised into a prominence termed
tubercle (fig. 289, *Ts*), and together with the part of the u
which is placed outside the groove, projects into the vent
corresponding cerebral hemisphere, and is covered by the
thelium of that cavity. This part of the upper surfac
externally by a white band, the stria terminalis, (*Sf*) whi
it from the part of the corpus striatum which is seen in
ventricle. The longitudinal groove appears to be caused by t
margin of the fornix, the edge of which extends over the su
thalamus along the line of the groove. The posterior an
of the upper surface behind the groove does not project int
third or the lateral ventricle, and is not covered with epithe
limited internally by a sharp edge which separates it from
surface and which is marked by the medullary stria above-n
leading to the pineal body. At the posterior and inner extre
thalamus, there is seen, as in front, a well-marked prominenc
tubercle or *pulvinar* (*Pv*)) which projects over and partia
the brachia of the corpora quadrigemina. Between this
and the peduncle of the pineal body (*Pen*) lies a small tri
pressed surface, separated posteriorly from the mesencephalon
verse groove and passing mesially into the stalk of the p
This triangular surface is termed the *trigonum habenulæ*.
surface of the thalamus has been already described in conn
the third ventricle. The posterior rounded surface is occu
entirely by the pulvinar. Below and external to this is anot
eminence termed the *outer geniculate body*, which is placed
the *inner geniculate body* before mentioned (p. 319), the two
rated from one another by one of the roots of the optic t
brachium) (fig. 261). From this brachium and from the tw
bodies the optic tract originates and curves downwards a
around the crus cerebri.

The external and under surfaces of the thalamus are not
united with other parts of the brain. The under surface is
the tegmental part of the crus cerebri, while the externa
covered by white substance which is formed of the fibres o
which here diverge into the substance of the hemisphe
between the thalamus and the lenticular nucleus forming
"internal capsule." More anteriorly the corpus albicans an
the tuber cinereum lie below the thalamus.

Structure.—The thalami optici are covered on their free surfac
upper), (fig. 291), by a layer of white fibres. On their outer su
mentioned, is the white matter of the inner capsule (*i. c.*) formed by
ing from the crusta into the hemispheres. Next to the thalamus o
denser layer of white fibres, termed the outer medullary lamin

adiating fibres pass out of the thalamus to mingle with the fibres of psule and to pass with these to the surface of the cerebral hemi-ose in front pass to the frontal lobe of the hemisphere; those in egion to the posterior part of the frontal and to the parietal lobe, to the temporo-sphenoidal; those behind to the temporo-sphenoidal l lobes. Continuous with these radiating fibres are others passing tract from the pulvinar. The lower surface of the thalamus is posteriorly with the prolongation of the tegmentum (subthalamic gion), but in front this prolongation inclines to the outer side and in a layer of grey matter which is continuous internally with the grey e floor of the ventricle, and is seen at the base of the brain as the an-ted lamina. Anteriorly the under surface of the thalamus is prolonged of fibres which curves downwards and outwards towards the white the hemisphere forming the so-called lower peduncle of the thala-these is another tract (*ansa lenticularis*) passing under the thalamus dial part of the crusta to the lenticular nucleus of the corpus striatum, ey substance being interpolated between the two tracts. These and ter between are termed collectively the *substantia innominata*.

Fig. 291.

CTION ACROSS THALAMUS AND IATUM IN THE THE MIDDLE (E.A.S., after n by Mr. S. G. Natural size.

us; *a*, *e*, *i*, its rnal and in-respectively; ed layer; *m*. commissure; low it is the e third ven-, corpus cal-nix, separated ird ventricle by the velum In the middle

seen the two veins of Galen and the choroid plexuses of the third l at its edges the choroid plexuses of the lateral ventricles; *t. s.*, tænia ; *cr*, forward prolongation of the crusta passing laterally into the internal *s. t. r.*, subthalamic prolongation of the tegmentum, consisting of (1) the (2) the zona incerta, and (3) the corpus subthalamicum; *s. n.*, substantia nucleus caudatus of the corpus striatum; *n. l.*, nucleus lenticularis; *e. c.*, le; *cl*, claustrum; *I*, island of Reil.

nce of the thalamus is chiefly formed of grey matter with nerve-ed in it, but their arrangement and connections with nerve-tracts therto been satisfactorily ascertained. Its grey matter is partially nto two parts, the so-called inner and outer nuclei of the thalamus by a vertical white lamina, S-shaped in section (inner medullary he *outer nucleus* (*e*), is the larger and extends into the posterior is marked externally by the radiating white lines before mentioned rom the thalamus into the inner capsule, and these confer upon its er somewhat of a reticulated aspect (latticed layer). The *inner* es not extend into the anterior tubercle, but this part of the grey sub-e thalamus is cut off from it by another septum of white matter. separated part is the *anterior nucleus* of the thalamus or *nucleus ior tubercle* (*a*). It contains comparatively large nerve-cells and th a number of fibres pass downwards and converge to form a bundle (bundle of Vicq-d'Azyr), which entering the corpus albicans that tubercle a sharp bend, and passes upwards again in the wall of as the anterior pillar of the fornix. The middle commissure unites

the inner nuclei across the third ventricle and is also continuous below on each side with the grey matter of the cavity. It contains transversely coursing fibres and nerve-cells.

In the *trigonum habenulæ* is a collection of nerve-cells termed by Meynert the *ganglion of the habenula*. From this a bundle of fibres is traceable downwards towards the interpeduncular region (the part between the cerebral peduncles) to another collection of nerve-cells, better marked in most animals than in man, termed the *interpeduncular ganglion* (Forel).

The *outer geniculate body*, darker in colour than the rest of the external nucleus of the thalamus to which it is attached, has a lamellated structure (fig. 288, *c.g.e.*); thin layers of white fibres derived from the optic tract alternate with thicker layers of grey matter containing large, pigmented, multipolar nerve-cells. The actual connection of the fibres with the cells has not been traced, but there is no doubt that this prominence and the neighbouring part of the thalamus are connected with the origin of the optic fibres, from the atrophy which they undergo after extirpation of the opposite eye.

The *inner geniculate body*, also continuous with the grey substance of the thalamus, lies below and mesial to the external geniculate body and resting inferiorly and on its inner side the brachium of the lower quadrigeminal body which dips underneath it. Externally and in front fibres pass out from it to join the optic tract. It is believed that these fibres are of commissural nature and are not continued into the optic nerve, for they, as well as the inner geniculate body, remain unaffected by extirpation of the opposite eye.

Subthalamic tegmental region.—The prolongation of the tegmentum under the posterior part of the thalamus is divided by Forel into three layers, which are named respectively from above down, the stratum dorsale, the zona incerta and the corpus subthalamicum (fig. 291, *s. t. r.*, 1, 2, 3). The latter is bounded below by a continuation of the substantia nigra, separating it from the prolongation of the crusta, the fibres of which are seen diverging at the side of the subthalamic tegmental region into the inner capsule. The *dorsal layer* consists chiefly of fine longitudinal fibres—prolonged from the posterior longitudinal bundle according to Meynert, from the fibres enclosing the tegmental nucleus (derived therefore from the superior cerebellar peduncles) according to Forel. It is continuous laterally with the latticed layer and external medullary lamina of the thalamus, into which some of its fibres pass, whilst others, coursing through the zona incerta, enter partly the inner capsule, and partly the substantia innominata, joining a tract which leads to the lenticular nucleus of the corpus striatum.

The *zona incerta* is a reticular formation prolonged from that of the mesencephalon; it passes anteriorly into the substantia innominata.

The *corpus subthalamicum* is a well-marked brown stratum of grey matter containing numerous pigmented nerve-cells. It is lens-shaped in section, and has an enclosing envelope of white substance, through which strands of fine fibres pass from the interior of the body mesially towards the posterior perforated lamina, and outwards and downwards into the crusta. This stratum is distinct only in the Primates.

The **pineal body** or **gland** (conarium) (fig. 289 *Cn*, fig. 290, *p*), is a reddish body of about the size of a small cherry-stone, and is named from its supposed resemblance in shape to a fir-cone. It is connected with the posterior part of the third ventricle, projecting backwards and downwards between the superior pair of corpora quadrigemina. It is attached by a broad but flattened stalk which is separated by the recess of the ventricle before mentioned (p. 321) into an upper and under portion, the latter of which curves downwards and passes below into the posterior commissure, while the upper portion extends on either side along the ridge-like junction of the upper and mesial surfaces of the thalamus as the medullary stria or peduncle of the gland (fig. 290, *s p.*) At the sides the stalk passes into the trigonum habenulæ. The pia mater

h invests the mesencephalon, covers the pineal gland with a special **ment** before being prolonged as the velum interpositum over the **ventricle** and thalamus; and the gland is liable to be torn away **oving** the pia mater.

icroscopic structure the pineal gland somewhat resembles the anterior **the** pituitary body. It is similarly composed of a number of hollow follicles **lly** spherical, but in some cases tubular, separated from one another by in- **s of** connective tissue. The follicles are almost filled with epithelial **nd** often contain, besides corpora amylacea, much gritty calcareous **(acervulus** cerebri, brain sand), composed of microscopic particles, aggre- **nto masses** and formed of earthy salts (phosphate and carbonate of lime, **a little** phosphate of magnesia and ammonia) combined with animal

abulous matter is frequently found on the outside of the pineal body, or **eposited** upon its peduncles. It is found also in the choroid plexuses; and **attered** form occurs in other parts of the membranes of the brain. It is **at all** ages, frequently in young children, and sometimes even in the fœtus. **not,** therefore be regarded as the product of disease. Huschke has pointed **at the** pineal body is larger in the child and the female than in the adult

In the brains of other mammals it is proportionally larger than in the **n subject,** and less loaded with brain sand. The pineal body is developed **ally as a** hollow outgrowth from that part of the embryonic brain which **rards** forms the third ventricle; the diverticulum becoming subsequently **f from** the ventricle, and undergoing ramification to form tubes which are **rards** separated for the most part into isolated vesicles.

e posterior perforated space (locus perforatus posticus) (fig. **x**) is a deep fossa at the base of the brain, at the bottom of which **yish** matter, connecting the diverging crura. It is perforated by **erous** small openings for the passage of blood-vessels; and some **ontal** white striæ usually pass out of the grey matter and turn **d** the peduncles close to the upper border of the pons to reach **tually** the medullary centre of the cerebellum (*tænia pontis*). It **sponds** posteriorly, as far as a line joining the anterior borders of **third** nerves, to the floor of the aqueduct of Sylvius, but in front of **e** nerves to the posterior part of the floor of the third ventricle. In **grey** matter over the space are a few scattered nerve-cells.

he corpora albicantia or **mammillaria** (fig. 260, *a*) are two **d** white eminences in front of this fossa, each about the size of a **l** pea, connected together across the middle line. Each corpus **ans** contains a nucleus of grey matter concealed within its superficial **e** fibres.

e corpora albicantia are formed, as will hereafter be explained, by the **ior** pillars of the fornix; hence they have also been named *bulbs of the* **e.** In most vertebrate animals there is but one median corpus albicans in **of** two.

e tuber cinereum (figs. 260, 290, *t c*) is a lamina of grey matter **ding** forwards from the corpora albicantia to the optic commissure, to **h it is** attached. It forms part of the floor of the third ventricle. In **middle** it is prolonged forwards and downwards into a hollow conical **s,** the **infundibulum** (fig. 292, *i*), to the extremity of which is **the** pituitary body. On its outer side close to the optic tract is a **tion** of grey matter with nerve-cells, termed by Meynert the *basal ganglion,* from which fibres arise which pass to the optic tract and **nerve** of the same side.

The **pituitary body** or *hypophysis cerebri* (fig. 260, 261, *h*, and fig. 292), formerly called pituitary gland, from its being erroneously supposed to discharge *pituita* into the nostrils, is a small reddish grey mass of somewhat flattened oval shape, widest in the transverse direction, occupying the sella turcica of the sphenoid bone. Its weight is from five to ten grains. It consists of two lobes, of which the anterior is larger, and concave behind, where it embraces the smaller posterior lobe.

The two lobes are entirely different, both in their structure and development, and it is only in mammals that they come into close connexion with one another. The *posterior lobe* is developed as a hollow downgrowth of the part of the cavity of the embryonic brain, which afterwards becomes the third ventricle. In the lower vertebrates, and especially in fishes, the cells which compose its walls become converted into nerve-cells and fibres, and as the *lobus infundibuli* it becomes an integral part of the brain. But in the higher vertebrates it remains

Fig. 292.

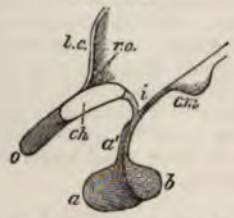


Fig. 292.—SAGITTAL SECTION OF THE PITUITARY BODY AND INFUNDIBULUM WITH THE ADJOINING PART OF THE 3RD VENTRICLE (Schwalbe).

a, anterior lobe; *a'*, a projection from it towards the front of the infundibulum, *i*; *b*, posterior lobe connected by a solid stalk with the infundibulum; *l. c*, lamina cinerea; *o*, right optic nerve; *ch*, section of chiasma; *r. o*, recess of the ventricle above the chiasma; *c. m*, corpus mammillare.

small and almost undeveloped; its cavity is obliterated, and all nervous structure becomes obscured by the ingrowth of vessels and of connective tissue into the now solid organ. The connective tissue forms reticulating bundles, between which occur numerous spindle-shaped and branched cells, as well as a few larger corpuscles containing pigment-granules in their protoplasm. Sometimes remains of the original hollow are seen in the form of a cavity lined by columnar ciliated cells.

The *anterior lobe*, darker in colour than the posterior, is developed as a tubular prolongation from the ectoderm of the buccal cavity, with which it is therefore originally in connection, although it soon becomes separated by the growth of intervening tissue. In the adult it is constituted by a large number of slightly convoluted tubules or alveoli, similar to those of a secreting gland, and in like manner lined by epithelium, which in some cases fills up the tubule. The tubules are united by connective tissue, which is especially abundant in the neighbourhood of the larger blood-vessels, and also forms a sort of capsule to the organ. Moreover, portions of the tubules are frequently cut off by the connective tissue so as to form isolated vesicles. The outer layer of epithelium is columnar; and in some of the larger tubes, especially those next to the posterior lobe, cilia may be detected on the cells. The blood-vessels are numerous, and the capillaries form a close network around the walls of the tubules. The lymphatics of the organ originate in cleft-like spaces between the tubules and pass to a network in the capsule. In its microscopic structure the anterior lobe of the pituitary body approaches closely that of the thyroid body, the vesicles of which are also originally a network of anastomosing tubules, and in some animals remain throughout life in this condition. Moreover, a colloid substance like that in the thyroid vesicles, is found sometimes in the alveoli of the anterior lobe of the hypophysis.

The **optic commissure**, or *chiasma* (fig. 260), is constituted by the union of the two optic tracts in front of the tuber cinereum, and from it the two optic nerves proceed. In it the nerve-fibres of the two sides undergo a decussation. Their arrangement in the decussation will be more fully considered when the origin of the optic nerve is described.

Each cerebral hemisphere has an outer, convex surface, in contact with the vault of the cranium ; an inner or median, flat surface, which forms one side of the longitudinal fissure ; and an irregular under surface, in which is a deep cleft, the fissure of Sylvius. In front of the cleft the under surface rests in the anterior fossa of the base of the skull, and behind it in the middle fossa, and further back still, on the tentorium cerebelli.

The **great longitudinal fissure** (fig. 293, *l l*), seen upon the upper surface of the brain, extends from before backwards throughout its whole length in the median plane, and thus separates the cerebrum, as already stated, into a right and left hemisphere. On opening this fissure, it is seen, both before and behind, to pass quite through to the base of the cerebrum ; but in the middle it is interrupted by a large transverse mass of white substance, named the *corpus callosum* or great commissure, which connects the two hemispheres together. While the brain is within the skull, this fissure is occupied by a vertical process of the dura mater —the falx cerebri—which dips down between the two hemispheres, not quite reaching to the corpus callosum in front but touching it behind.

At a short distance beneath the anterior recurved end of the corpus callosum and outwards from the lamina cinerea there is seen at the base of each hemisphere the **anterior perforated space** (locus perforatus anticus), a depression near the entrance of the Sylvian fissure, floored with grey matter, and pierced with a multitude of small holes for the passage of blood-vessels, most of which are destined for the corpus striatum, beneath which it lies, and which here comes to the surface.

The grey surface of each perforated space is crossed by a broad white band, which may be traced from the corpus callosum, backwards and outwards along the side of the lamina cinerea towards the entrance of the Sylvian fissure. These bands of the two sides are named the *peduncles of the corpus callosum*.

The surface of the hemispheres is composed of grey matter, and is moulded into numerous smooth and tortuous eminences, named *convolutions* or *gyri*, which are marked off from each other by *furrows* or *sulci* of varying depth.

The convolutions are covered closely throughout by the vascular investing membrane, the pia mater, which sends processes down to the bottom of the sulci between them, while the arachnoid membrane passes from one convolution to another, without dipping between them. In general, the depth of a convolution exceeds its thickness ; and its thickness, near the summit, is somewhat greater than through its base. The convolutions present considerable variations of position, direction and complexity in the brain of different individuals, and even in the two sides of the same brain.

Since the external grey or cortical substance is continuous over the whole surface of the cerebral hemispheres, being found alike within the sulci and upon the gyri, it is obvious that a far greater extent of grey matter is thus exposed to the vascular surface of the pia mater with a given size of the brain, than could have been the case had the hemispheres been plain and destitute of convolutions.

The sulci between the convolutions are generally from half an inch to an inch in depth, but vary in this respect both in different brains and in different parts of the same brain. In general certain well-marked furrows

The *furrow of Rolando* or *central sulcus* (fig. 296, *f. Ro.*; and 293, *r*), extends across the lateral convex surface of the hemisphere, interrupting the general longitudinal course of the gyri and sulci. It commences above, near the vertex, close to the great longitudinal fissure, and passes downwards and forwards to end a little behind the bifurcation of the fissure of Sylvius, into the posterior limb of which it sometimes but very rarely opens. Its position and direction are such that the fissures of the two sides, seen from above, form a wide V-shaped figure open in front. It is rarely interrupted in its course, appears early in fœtal life (end of the fifth month), and is very uniform in man and in the Quadrumana of the old world, but is not present in mammalia generally. It is apparently caused by a venous communication between the superior longitudinal sinus and the middle cerebral vein, which is well marked in the fœtus from the fourth to the sixth month, but afterwards becomes atrophied (W. Krause).

This furrow separates the frontal from the parietal lobe. The parietal convolutions which bound it are named respectively the ascending frontal and ascending parietal convolutions.

It is in the immediate neighbourhood of this sulcus that the chief of the so-called motor areas of the cerebral cortex are situated.

Fig. 294.

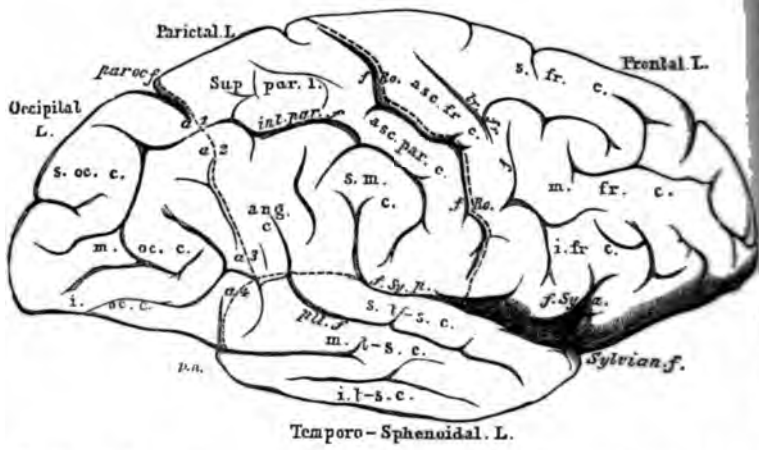


Fig. 294.—Convolutions of outer surface of right hemisphere. From a simple-convoluted European brain. About half the natural size (W. R. Gowers).

The convolutions are, for the most part, indicated by Roman, the furrows by italic letters. The dotted lines indicate the divisions into lobes, the names of which are given in full at the margin of the hemisphere. *f. Ro.*, furrow of Rolando; *par.-oc. f.*, parieto-occipital fissure; *f. Sy. a.*, anterior limb, and *f. Sy. p.*, posterior limb, of the fissure of Sylvius: s.fr.c., m.fr.c., i.fr.c., superior, middle, and inferior frontal convolutions; asc.fr.c., ascending ditto; asc.par.c., ascending parietal convolution; sup.par.l., superior parietal lobule; s.m.c., supra-marginal convolution; ang.c., angular convolution; *int. par. f.*, intra-parietal furrow; s.oc.c., m.oc.c., i.oc.c., superior, middle, and inferior occipital convolutions; *p. n.* pre-occipital notch; s.t.-s.c., m.t.-s.c., i.t.-s.c., superior, middle, and inferior temporo-sphenoidal convolutions *pll. f.*, parallel furrow; a^1, a^2, a^3, a^4; first, second, third and fourth annectant convolution; C. L., within the fissure of Sylvius, central lobe, or Island of Reil.

therefore, prominent; but it becomes gradually covered in b
of the hemisphere which are subsequently developed.

Olfactory lobe.—From the front of the anterior perf
a nerve-like process extends—the olfactory tract (fig. 296, *o*
lodged in a hollow (olfactory sulcus) in the under (orbital)
the frontal lobe of the cerebral hemisphere, close to the l
fissure. It ends in front in an oval swelling—the olfa
which consists chiefly of grey substance, and gives origin t
nerves which proceed, through the foramina of the ethmoid
nose. Traced backwards, the olfactory tract bifurcates nea
of the anterior perforated space, and is continued into tw
white bands or striæ, which are known as its roots. The

Fig. 296.

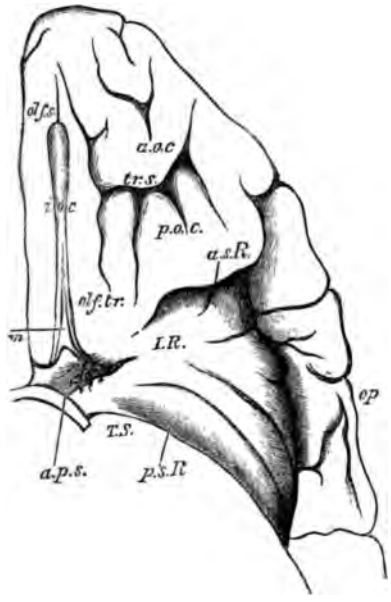


Fig. 296.—ORBITAL SUR
FRONTAL LOBE, AND ISL
Natural size. (Turner).

The island (*I.R.*) is expos
of the apex of the temp
lobe. *T.S.*, cut ridge o
a.p.s., anterior perforated
p.s.R., anterior and post
sulci of the island; *op*,
the island. *tr.s.*, tri-ra
i.o.c., *a.o.c.*, and *p.o.c.*,
terior, and posterior orb
tions; *olf.s.*, end of the olfa
olf.tr., olfactory tract, bi
hind into the two roots inn
m, middle root or tuber olfa

passes, as a white s
wards and backwards
anterior margin of the
space, towards the S
sure, where it disap
the surface. The
passes obliquely inwa
side of the great l
fissure between the h
Between the two ro
angular area of grey
enclosed, which is continuous behind with the grey mat
anterior perforated lamina. The area in question forms
a small pyramidal lobule, named the *tuber olfactorium*, w
ceived into a corresponding depression on the under surfa
frontal lobe, with the grey cortex of which it is conti
is composed of white substance internally, which is in
above with that of the frontal lobe, and anteriorly with th
tract.

This olfactory tubercle is often described as the *middle or grey* olfactory tract: and white fibres are sometimes prolonged from that surface and pass to the anterior perforated lamina.

The **Frontal Lobe** is the portion of the brain in front of
of Rolando, and above and in front of the fissure of Sylviu

surface there is no corresponding demarcation, unless the marginal furrow is regarded as forming a boundary to the lobe surface. The inferior surface of the frontal lobe, which is in with the orbital plate, is called the *orbital surface;* the upper aspect is the *frontal surface.*

volutions and furrows on the frontal surface.—The convolu- of the frontal lobe on the frontal surface, are four in number, three posterior, one above the other, and one transverse behind them.

transverse or *ascending frontal convolution* (fig. 294, asc. fr. c., fig. A.) (anterior central convolution) is placed in front of the furrow lando, which it thus bounds. Below, it commences a little behind ifurcation of the fissure of Sylvius, and thence courses upwards and wards to the margin of the great longitudinal fissure. Its prolonga- on the median surface of the hemisphere forms part of the paracentral e. It is commonly connected above, and almost invariably below, the convolution (ascending parietal) behind the furrow of Rolando, thus that sulcus is isolated.

e portion of the frontal surface anterior to this convolution is pied by complex gyri running more or less in an antero-posterior ction, and usually to be distinguished into three, an upper, middle, lower. These are generally continuous superficially with the ascend- frontal; and they are usually in their course connected one with ther by secondary convolutions. They are as follows :—

he *superior frontal convolution* (s. fr. c.), situated at the margin of great longitudinal fissure, commences generally at the upper end of ascending frontal, and extends to the anterior extremity of the misphere, where it passes over to the orbital surface and becomes the er convolution. The inner aspect of this convolution appears on the dian surface of the hemisphere, where it is known as the marginal volution.*

The *middle frontal convolution* (m. fr. c.) arises deeply or superficially m the ascending frontal below the last, and running forwards turns und the margin of the lobe to become continuous with the middle bital. It is usually broad, and often much subdivided.

The *inferior frontal convolution* (i. fr. c.) forms the lower and outer portion of the frontal lobe. It arises from the lower extremity of he ascending convolution, just above the bifurcation of the fissure of Sylvius, arches round the ascending limb of that fissure, and passes on to the inferior surface of the hemisphere, as the posterior orbital gyrus.

The *transverse frontal furrow* (*tr. fr.*) (præcentral sulcus) lies in front of the ascending frontal convolution, and parallel to the lower half of the furrow of Rolando. Its extent depends on the mode of origin of the middle and inferior frontal convolutions from the ascending frontal. When these arise superficially the furrow is interrupted, and may be inconspicuous; when the inferior frontal convolution arises deeply, this furrow is continuous with the fissure of Sylvius, and it has, in consequence, been regarded as the prolongation of the ascending limb of that fissure.

Two *antero-posterior sulci*, the *superior* and *inferior frontal*, separate

* It will be convenient to defer the complete description of the convolutions which appear on the median surface, until that surface is considered as a whole.

the corresponding convolutions from the middle frontal: they are ... very irregular, being bridged over by secondary convolutions.

Convolutions and furrows on the orbital surface (fig. 296).—... *orbital* or *tri-radiate sulcus* lies in the centre of this surface of the ... and usually has three arms, one passing forwards, one curving outw... and another backwards and inwards.

Three convolutions are described as lying around the orbital ... and named according to their position, the *inner*, the *anterior*, and ... *posterior* or *outer*. The last of these is continuous at the side with ... inferior frontal, the first and second are the continuations of the sup... and middle frontal convolutions.

On the inner gyrus is seen the *olfactory sulcus* in which the olfac... tract and bulb lie. It has a straight course parallel with and near ... great longitudinal fissure.

The **Parietal Lobe** lies behind the frontal and in front of ... occipital lobe. The temporo-sphenoidal lobe is below it. It is boun... in front by the sulcus of Rolando, behind by the parieto-occip... fissure, and by a continuation of the line of that fissure to the late... boundary. It is limited by the posterior limb of the fissure of Sylv... as far as this preserves its horizontal direction, and then by a li... continuing that direction to the posterior boundary, but above ... mesially it extends within the great longitudinal fissure and appears ... the inner side of the hemisphere.

Sulci and gyri of the parietal lobe.—The *intraparietal sulcus* (fig. 294, *int. par. f.*) arches through the parietal lobe, commencing ... its anterior inferior angle, where it is sometimes, though rarely, con... tinuous with the fissure of Sylvius. It ascends at first parallel to the ... furrow of Rolando, and then turns backwards horizontally to the back ... of the lobe, extending nearly to the termination of the external parieto-occipital fissure, past which it is often continued into the occipital lobe. Its horizontal portion divides the parietal lobe into two parts, the superior and inferior parietal lobules, and it is frequently bridged across by a secondary convolution connecting those lobules.

The *ascending parietal* (or posterior central) *convolution* (fig. 293, B, B, fig. 294, asc. par. c.) lies behind the sulcus of Rolando, and parallel to the ascending frontal convolution, with which it is usually continuous, both above and below, the connection below being larger than that above. In its lower half the ascending parietal convolution lies in front of the anterior part of the intraparietal sulcus. Above, it is continuous with the superior parietal convolution.

The *superior parietal convolution or lobule* (fig. 294, sup. par. l.) is that part of the parietal lobe which lies above the intraparietal sulcus, and behind the upper part of the last described convolution, from which it is imperfectly separated by a slightly marked groove (postcentral sulcus) which is sometimes a branch of the intraparietal. Its posterior limit is the boundary of the parietal lobe, viz., the external parieto-occipital fissure, outside the extremity of which a narrow convolution usually connects this lobule with the occipital lobe, and is termed the first connecting or annectant convolution. The superior parietal is continuous on the mesial surface of the hemisphere with the quadrate lobule.

The *inferior parietal lobule* lies behind the ascending and below the horizontal part of the intraparietal sulcus. It is divided into two, a supramarginal gyrus, above and in front of the extremity of the

fissure, and an angular gyrus behind it. The *supramarginal* ion (s. m. c.) lies behind the lower end of the intraparietal sulcus, which it is usually continuous with the ascending parietal ion. It arches over the upturned extremity of the fissure of and becomes continuous with the superior temporo-sphenoidal ion. The *angular gyrus* (ang. c.) is connected in front with amarginal, bends over the end of the parallel sulcus, and is d downwards into the middle temporo-sphenoidal convolution. it is connected with the occipital lobe by means of one or two and third) annectant convolutions.

Occipital Lobe of pyramidal shape, lies behind the parietal, ns with its rounded apex the posterior extremity of the hemi- At its lower and fore part, it is continuous with the temporo- al lobe. It occupies the superior fossa of the occipital bone, s on the tentorium. Its limits are in some degree artificial. In is bounded by the external parieto-occipital fissure, and by a tinuing the direction of the fissure across the annectant con- s to meet the inferior boundary of the parietal lobe, and thence d to the lower edge of the external surface of the hemisphere nterior edge of the tentorium. There is generally a notch ipital notch, fig. 294, *p. n.*) at this lower border, and a curved ending from this notch to the parieto-occipital fissure, would f the lobe externally, often coinciding for a short distance with ue furrow which may be found running between it and the -sphenoidal lobe.

olutions and furrows of the occipital lobe.—On the dorsal sur- ee convolutions are commonly described, *superior, middle, and* (fig. 294). They are continuous with the convolutions of the and temporo-sphenoidal lobes by the four *annectant* or connecting *ions*, of which the *first*, passing round the extremity, or in rare eply across the bottom, of the external parieto-occipital fissure, s the superior occipital convolution with the superior parietal he *second* unites the middle occipital and angular convolutions, *d* connects the middle occipital with the lower end of the or the middle temporo-sphenoidal, and the *fourth* connects the occipital with the inferior temporo-sphenoidal convolution (a^1,). The three occipital convolutions are separated by two fur- e *superior and middle occipital*, of which the superior is often ous with the intraparietal. There is also generally a small groove outwards across the upper part of the occipital lobe a little he parieto-occipital fissure. This is named the *transverse occi- cus*, and represents the outer portion of the external perpendicular f the ape's brain.

e lateral edge of the lobe is another furrow, the *inferior occipital*, erves to separate the inferior occipital convolution from the -temporal on the under surface of the lobe. The superior l convolution on the other hand has no sulcus bounding it at the dge of the hemisphere, but passes continuously into the cuneate n the mesial surface.

e mesial (under) surface of the occipital lobe are the posterior the *occipito-temporal convolutions*, which, as well as the furrows ng them, will be described with the convolutions of the inner f the hemisphere.

The longitudinal venous sinus in passing downwards causes an impression on the posterior surface of the occipital lobe, at the mesial border (Bastian). This impression is generally found on the right side, but sometimes on the left.

The **Temporo-sphenoidal lobe** is bounded in front and above by the commencement and posterior limb of the fissure of Sylvius. Behind it is continuous with the occipital lobe, and above with part of the parietal lobe. It is somewhat pyramidal in shape, having three surfaces, viz., lateral, superior and inferior, the last concealed within the fissure of Sylvius. The rounded apex of the pyramid is free, and lies in front beneath the orbital surface of the frontal lobe from which it is separated by the broad commencement of the Sylvian fissure.

Sulci and gyri of the temporo-sphenoidal lobe.—The upper surface of this lobe is marked by two or three *transverse temporal gyri* (Heschl). On the lateral and under surfaces there are three sulci with an antero-posterior direction. The first or *superior temporo-sphenoidal sulcus*, also termed from its relation to the Sylvian fissure the *parallel sulcus* (*pll. f.*), is an important furrow, appearing in the sixth month, and being constant in the Primates. It is sometimes interrupted by a small gyrus connecting the convolutions above and below it. The *middle temporo-sphenoidal sulcus* runs parallel to and below the last but is far less constant in extent and direction. It is also generally interrupted by a vertical connecting gyrus. The *inferior temporo-sphenoidal sulcus* is seen on the under surface of the lobe extending behind nearly to the pre-occipital notch.

Three nearly parallel convolutions can usually be distinguished on the lateral surface of this lobe ; a *superior* (inframarginal (fig. 294, s.t-s.c.) bounding below the posterior limb of the Sylvian fissure, and continuous behind with the supramarginal and to a less extent with the angular convolution of the parietal lobe, a *middle* (m. t-s. c.) continuous with the angular gyrus, and with the middle occipital convolution by means of the third annectant gyrus, and an *inferior* (i. t-s. c.) continuous with the inferior occipital through the fourth annectant gyrus.

The anterior parts of the two *occipito-temporal convolutions* (the posterior parts of which belong to the occipital lobe) are seen on the under or mesial surface of the temporo-sphenoidal lobe. They are separated by the collateral fissure.

Gyri and sulci on the mesial and tentorial surfaces of the hemisphere (fig. 297). The following furrows and convolutions are seen on this surface :—

The *calcarine fissure* (fig. 297, *calc. f.*) commences by a forked end near the posterior extremity of the hemisphere, and extends forwards, being joined about half way in its course by the internal parieto-occipital, to terminate a short distance beneath the posterior extremity of the corpus callosum. It corresponds to the projection of the hippocampus minor (calcar avis) in the posterior cornu of the lateral ventricle.

The *calloso-marginal sulcus* (*c. m. f.*) commences beneath the anterior extremity of the corpus callosum, and courses first forwards, then upwards, and then backwards, parallel with the edge of the longitudinal fissure ; finally it turns obliquely or vertically upwards to end at this edge a short distance behind the upper extremity of the sulcus of Rolando. It separates the marginal convolution from the convolution of the corpus callosum.

The *hippocampal* or *dentate fissure* (*d.f.*) commences within the posterior

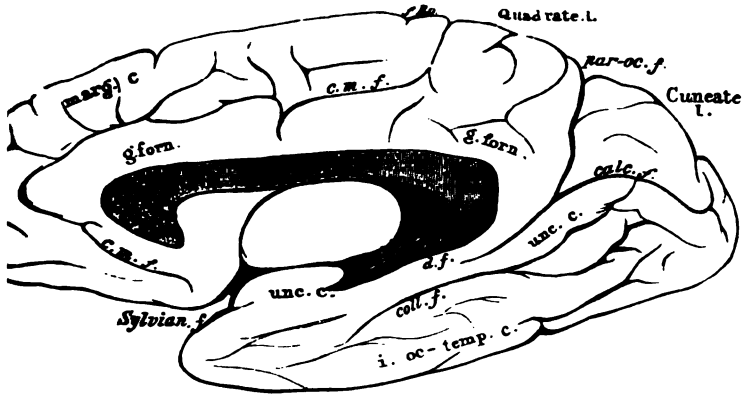
ity of the gyrus fornicatus, which separates it from the end of the e fissure. Thence it extends downwards and forwards, ending in the notch of the uncinate convolution. This fissure corresponds to vation of the hippocampus major in the floor of the lateral ventricle.

internal parieto-occipital fissure (*par-oc. f.*) is a large and deep which extends downwards and forwards to join the calcarine fis- It assists the calcarine in forming the projection into the lateral le known as the calcar avis.

collateral fissure (occipito-temporal, *coll. f.*) is so named from the fact tending deeply into the substance of the hemisphere it projects in cending cornu of the lateral ventricle as the *eminentia collateralis.* s between the superior and inferior occipito-temporal convolutions.

cuneate lobule (occipital lobule) is a wedge-shaped area lying be- the internal parieto-occipital and the calcarine fissures. As already it is the mesial part of the superior occipital convolution.

Fig. 297.



297.—CONVOLUTIONS OF THE MESIAL AND TENTORIAL SURFACES OF THE RIGHT EMISPHERE. FROM A SIMPLY CONVOLUTED EUROPEAN BRAIN. About half the natural (Gowers.)

rg. c., marginal convolution; *g. forn.*, gyrus fornicatus or convolution of the callosum; *unc. c.*, uncinate convolution; *i. oc.-temp. c.*, inferior occipito-temporal lution: *d. c.*, dentate convolution; *f. Ro.*, depression corresponding to the upper nity of the furrow of Rolando; *par.-oc. f.*, parieto-occipital fissure; *calc. f.*, cal- fissure; *coll. f.*, collateral fissure; *d. f.*, dentate fissure; *t. h.*, tænia hippocampi.

he *quadrate lobule* (præcuneus) is a four-sided area lying between internal parieto-occipital fissure behind, and the termination he calloso-marginal fissure in front. It is variously subdivided small gyri, and is continuous above with the superior parietal le, and below with the gyrus fornicatus. The quadrate lobule ngs to the parietal lobe of the hemisphere.

he *marginal convolution* (marg. c.) commences in front of the anterior rated spot, and extends along the edge of the longitudinal fissure as s the termination of the calloso-marginal fissure at the upper margin is surface. Over this margin it is continuous with the dorsal part e superior frontal convolution, and with the continuation of this on rbital surface. It is commonly broken up by secondary sulci, one

of which often runs parallel to part of the calloso-marginal s
secondary convolution not uncommonly connects it with the ne

The *convolution of the corpus callosum* or *gyrus fornicatus* (g. 297), commences near the anterior perforated spot, and, turni the anterior extremity of the corpus callosum, runs backwards upper surface, and then, bending down behind its posterior becomes continuous with the uncinate convolution. It is b front and superiorly for about two-thirds of its extent by th marginal fissure. Between it and the corpus callosum is a w groove—the furrow of the corpus callosum. The hinder part o fornicatus is connected above with the quadrate lobule, and j the uncinate convolution.

The *dentate convolution* (fascia dentata, fig. 297, d c, fig. 2 within the fissure of the same name. It is so termed from th appearance it presents in its lower part. It here forms the li superficial grey matter of the hemisphere, for immediately abov white fimbria or tænia hippocampi (*t h*) prolonged from the f above this again the invagination of the pia mater with its plexus into the lateral ventricle of the hemisphere. Both fasc and fimbria blend in front with the uncus. In some animals volution is much better developed than in man, in whom i paratively rudimentary

Fig. 298.

Fig. 298.—SECTION OF THE RIGHT HIPPOCAM TO SHOW THE ARRANGEMENT OF THE GREY SUBSTANCE (from Mayo).

a, white layer on the surface of the hippoc ing in the fimbria ; *b*, grey substance of the hi *c*, fascia dentata ; *d*, uncinate convolution ; bet *d* dentate fissure ; *e*, placed on the eminentia within the cavity of the lateral ventricle.

The *superior occipito-temporal* or *unc volution* extends forwards from near terior end of the hemisphere to within a short distance of of the temporo-sphenoidal lobe. Anteriorly it is bent sharpl a hook-like extremity (*uncus*). Beneath the posterior extremi corpus callosum this convolution is joined by a narrow part of the gyrus fornicatus. Above are the hippocampal and cal sures, whilst the collateral fissure runs below it. The grey mat anterior half of this gyrus is covered by a reticular layer of w stance derived from the tænia of the corpus callosum. The p the calcarine fissure is sometimes distinguished by the nam *lingual lobule.*

The *inferior occipito-temporal convolution* is of considerab extending from the apex of the temporo-sphenoidal lobe bac near the posterior extremity of the hemisphere. It lies bet collateral fissure and the inferior temporo-sphenoidal sulcus.

Limbic lobe.—Most of the convolutions on the inner surface of sphere can be referred to one or more of the lobes marked out on t or dorsal surface. But this is not the case with the gyrus fornicatus longation the anterior part of the uncinate gyrus, which are for the well marked off in nearly all mammals from the surrounding convolu

and other reasons they have been regarded by Broca as constituting a
ct lobe of the hemisphere (grand lobe limbique).
the parts included in this lobe of Broca Schwalbe adds the other central
of the mesial wall of the hemisphere, viz., the lamina septi lucidi and the
e convolution, as well as the fornix which may be said to unite them;
upon these as representing an inner encircling convolution concentric
the gyrus fornicatus and uncinatus, and naming the whole lobe thus consti-
the "falciform lobe."
is worthy of note that the two ends of the limbic lobe of Broca, which are
ited by the deep part of the Sylvian fissure, are indirectly united with one
er by the roots of the olfactory tract, so that the olfactory lobe, of which
forms a part, is in intimate connection with the limbic lobe. This connec-
is much more conspicuous in animals.

LATION OF THE CEREBRAL FISSURES AND CONVOLUTIONS TO THE CRANIAL SUTURES.

This relation was first determined exactly by Broca, and subsequently
been more extensively mapped out by Turner and Hefftler. Broca
ed pins through the cranium at particular points in the cranial
s, and noted the situation of the chief fissures with reference to
parts of the cerebral surface pierced by the pins. Turner's method
sted in carefully removing successive portions or regions of the
nial wall, and delineating upon the removed parts the fissures which
e exposed by their removal.
The most important facts which have been determined by these

Fig. 299.

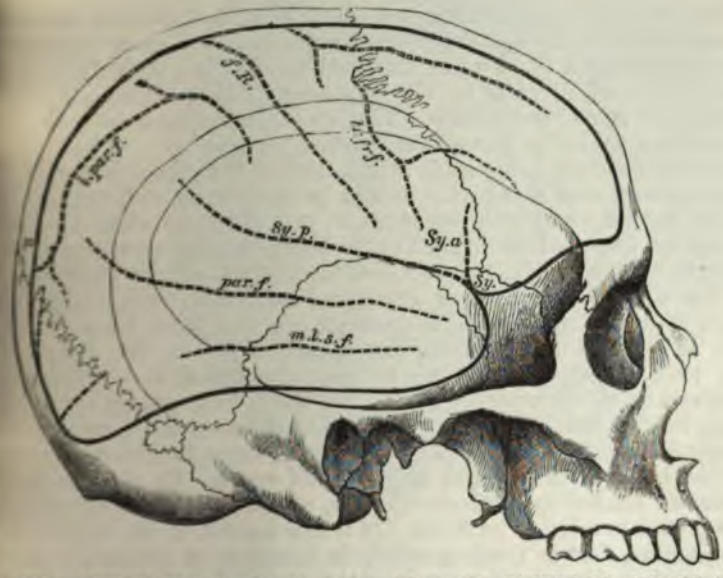


Fig. 299.—OUTLINE SKETCH OF THE SKULL, WITH THE POSITION OF SOME OF THE PRINCIPAL CEREBRAL SULCI MARKED UPON IT (from a drawing by G. D. Thane). ½

Sy. Sylvian fissure; *Sy.a.*, *Sy.p.*, its anterior and posterior limbs; *f.R.*, furrow of Rolando; *tr.fr.f.*, transverse frontal furrow; *i.par.f.*, intraparietal furrow; *p.o.*, position of the parieto-occipital fissure; *par.f.* parallel furrow; *m.t.s.f.*, middle temporo-sphenoidal furrow.

methods refer to the Sylvian fissure, the parieto-occipital fissure, s
sulcus of Rolando.

The Sylvian fissure.—The commencement of this nearly
sponds with the suture which unites the anterior inferior angle
parietal bone with the great wing of the sphenoid. From this
the anterior limb passes up for a short distance nearly parallel wi
close to the coronal suture, whilst the posterior limb runs at first
the line of the squamous suture, but afterwards, as this arches
wards, is continued beyond it, curving slightly upwards towar
middle of the parietal bone.

The **parieto-occipital fissure** generally corresponds to the
end of the lambdoidal fissure, being on a level with the *lambda* (see V
p. 80).

The **sulcus of Rolando** runs behind the coronal suture, but sep
from it by a considerable interval. It is not exactly parallel to
suture, being about one and a half to two inches from it above,
approaching nearly to a distance of one inch from it towards the l
end.

The usual position of several of the other sulci of the outer surface is indi
in the accompanying figure.

INTERNAL PARTS OF THE CEREBRAL HEMISPHERES.

The anatomy of the interior of the cerebrum is most convenie
studied, after the manner of Vieussens and Vicq-d'Azyr, by remov
successive portions of the hemispheres by horizontal sections, begin
from above.

The first horizontal section, to be made about half an inch above t
corpus callosum, displays the internal white matter of each hemisphe
speckled with red spots where its blood-vessels have been divided,
surrounded on all sides by the grey matter, which is seen to fol
closely the convoluted surface. This white central mass in each he
sphere was named by Vicq-d'Azyr *centrum ovale minus*.

Another section being made at the level of the corpus callosum, t
white substance of that part is seen to be continuous with the inter
medullary matter of both hemispheres: and the large white medull
mass thus displayed, surrounded by the border of cortical substance, co
stitutes what is generally described as the *centrum ovale of Vieussens*.

The **corpus callosum** or **great commissure** (trabs cerebri) (fig.
300), a white structure which connects the two hemispheres throug
out nearly half their length, approaches closer to the front tha
the back of the hemispheres. It is about an inch in width behind,
and somewhat narrower in front. Its thickness is greater at the ends
than in the middle, and is greatest behind, where the commissure is
nearly half an inch thick. It is arched from before backwards, its lower
surface being concave and its upper surface convex. Its upper surface is
distinctly marked by transverse furrows, which indicate the direction of
the greater number of its fibres. It is also marked in the middle by a
longitudinal furrow (*raphe*), which is bounded by two white tracts,
placed close to each other, named the *mesial longitudinal striæ* (fig.
300, 3). On each side, near the margin, are seen other longitudinal
lines (*lateral longitudinal striæ* or *tæniæ tectæ*) occasioned by scanty
white fibres, which form part of a larger bundle lying in the substance
of the hemisphere.

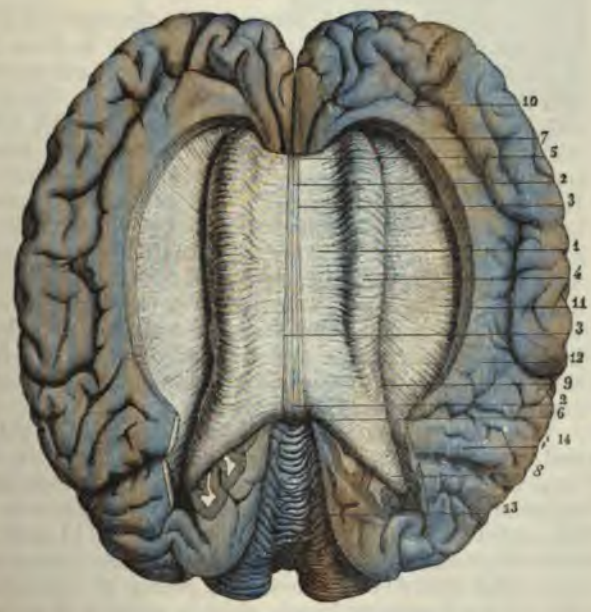
t, the corpus callosum is reflected downwards and backwards,
bend named the *genu* (fig. 258). The inferior or reflected
hich is named the *rostrum*, becomes gradually narrower as it
and is connected with the lamina cinerea. It gives off also
s of white substance, the *peduncles* of the corpus callosum,
verging from one another, run backwards across the anterior
l space on each side to the entrance of the Sylvian fissure
30). These peduncles traced upwards around the genu are
be continued into the mesial longitudinal striæ, which pos-
ass in a divergent manner into the occipital lobes.

, the corpus callosum terminates in a free thickened border,
e *splenium*.

der surface of the corpus callosum is connected behind with
, a structure to be presently described, and in the rest of its
th the septum lucidum, a vertical partition between the two
ntricles, which is included in the anterior bend of the corpus

On the sides the corpus callosum roofs in the body and
ornu of the lateral ventricles. The enlarged posterior part or
lies over the mesencephalon, with pia mater between.

Fig. 300.



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ey pass into the cerebrum, arching over the side of the lateral ventricle; 5, tremity or knee of the corpus callosum; 6, posterior extremity; 7, anterior, terior fibres proceeding from the corpus callosum into the frontal and occipital tively; 9, margin of the swelling; 10, anterior part of the gyrus fornicatus; between the corpus callosum and this convolution opened out; outside 12, is ation of the calloso-marginal fissure, and before 13 is the parieto-occipital upper surface of the cerebellum

Although it has a few longitudinal white fibres on its surface, the corpus callosum consists almost entirely of fibres having a transverse course, spreading on each side in a radiating manner into the substance of the hemispheres. The greater thickness of the corpus callosum at its anterior and posterior extremities than in the intervening part is due to the increased aggregation of the fibres in the two former situations, and the greater thickness of the posterior extremity is attributable to the mass of the cerebral hemisphere which is behind the corpus callosum being larger than that in front.

The fibres are arranged in flattened bundles with the long axes of the bundles vertical but becoming horizontal at the ends. In their passage into the parietal lobes and into the posterior part of the frontal lobe their direction is nearly transverse, but from the genu they curve round into the anterior part of the frontal lobe, and from the posterior end or splenium they arch round the posterior and inferior cornua of the lateral ventricle, forming the upper and outer wall of those parts of the cavity, into the temporo-sphenoidal and the lower part of the occipital lobes. Lastly, from the under part of the splenium fibres pass with a bold sweep (forceps major) into the posterior and superior parts of the occipital lobes.

Ventricles of the cerebral hemispheres, lateral ventricles or *ventriculi tricornes*.—By making a longitudinal cut through the corpus callosum at a short distance on each side of the middle line, and about midway between the two ends of the hemispheres, an opening is made into the right and left *lateral ventricles* (ventricles of the cerebral hemispheres).

Each lateral ventricle is connected by the cleft-like foramen of Monro with the anterior part of the third ventricle. In front of this communication the ventricle passes with a slight curve outwards and downwards into the frontal lobe of the hemisphere to form the *anterior cornu* (fig. 301, *g*), behind, the cavity extends backwards, with a slight curve outwards, as the *body of the ventricle* beneath the lateral part of the corpus callosum, and reaching as far back as the splenium of the latter. Here it bifurcates into a shorter *posterior cornu* (*h*), curving inwards and backwards into the occipital lobe, and a longer *inferior or descending cornu* (*q*), curving downwards and forwards to about an inch from the apex of the temporo-sphenoidal lobe. The whole cavity has therefore a general arched form, well shown in casts of the interior, the convexity of the arch being directed backwards, outwards and downwards, with an anterior and a posterior prolongation, this form having been assumed with the successive development of the lobes of the hemisphere around the first-formed central lobe.

The *body* of each lateral ventricle is roofed by the corpus callosum and its lateral extension, and is separated from its fellow by a hollow vertical partition, the *septum lucidum*, which extends between the corpus callosum and the fornix. In the floor of the ventricle there are seen in succession from the inner side and behind, (1) part of the *fornix*, a thin longitudinal layer of white substance, broader behind than in front (fig. 301, *f*): (2) the *choroid plexus of the lateral ventricle* (fig. 301, *c*), a red vascular fringe, which is covered by epithelium continuous with that lining the ventricle, and projecting from below the fornix, forms the border of the velum interpositum: (3) part of the *optic thalamus*, appearing from beneath the choroid plexus (fig. 301, *l*): (4) a narrow flat band, the *tænia semicircularis* or *stria terminalis* (*s*), which separates the optic thalamus from: (5) an elongated pyriform eminence of grey matter which extends into the anterior and inferior cornua, and is known as the *nucleus caudatus of the corpus striatum* (*k*).

nterior cornu (fig. 301, *g*) is the blind anterior extremity of the , projecting a little way into the white substance of the frontal t is covered by the corpus callosum, and turns forwards and out- und the enlarged anterior extremity of the nucleus caudatus, de- as it proceeds, and bounded below and externally by that body, by the reflected part of the corpus callosum, and mesially by ım lucidum.

—THE LATERAL LES OPENED BY L OF THE MID- T OF THE CORPUS M, AND THE DE- G CORNU EXPOSED RIGHT SIDE. ½

Fig. 301.

nterior and pos- ts of the great l fissure; *c*, the anterior part ous callosum; *d*, art of the same; choroid plexus; nix; *g*, the an- the posterior, descending cornu teral ventricle; ora striata; *l*, *l*, alami; *n*, *n*, left hippocampus posterior pillar nix; *v*, the fim- which it passes; cornu ammonis mpus major; *h*, medullary sub- the cerebral ; *r*, part of the ical substance e white stria of Vicq-d'Azyr; *s*, tænia semicircularis; *y*, eminentia collateralis.

ferior or *descending cornu* (*q*) turns round the back part of the lamus, which is separated from its cavity by the choroid plexus epithelial covering. At its commencement it is directed back- d outwards; then, passing downwards with a sweep, it curves , and at its extremity has a marked inclination inwards. Its ormed by the fibres of the corpus callosum which are arching pass to the temporo-sphenoidal lobe, and into it is prolonged a tion of the tænia semicircularis and the posterior tapering part cleus caudatus, already seen in the body of the ventricle. Near of the cornu a considerable prominence, the *amygdaloid tubercle*, the roof, and forms also the terminal boundary of the cornu. cipal object upon its floor is the *hippocampus major* (*cornu*), a large white eminence extending the whole length of the g. 302, 5′, 6′). This eminence becomes enlarged towards or and lower extremity, and is indented or notched on its edge, so sent some resemblance to the paw of an animal (pes hippocampi). te fibres of its surface form only a thin layer, and beneath grey matter continuous with that of the surface of the hemi- his eminence within the ventricle corresponding to the depres-

sion of the hippocampal fissure on the outside. Along th mesial edge of the eminence the white superficial layer (fig. thickened to form a narrow white band named *fimbria hippocampi* (fig. 302, 6), which is prolonged from the poste of the fornix; mesial to and above the fimbria is a part of t plexus, covered next the cavity by epithelium prolonged from the cavity. If the pia mater with the choroid plexus be pu the epithelium covering the latter is removed with it, and th made to communicate with the surface of the brain along length of its inner side (inferior fissure of the cerebrum).

The grey matter of the hippocampus major is continuous and below with that of the uncinate convolution and inter the fascia dentata, which forms, as shown in figure 298, a fr the superficial grey matter of the hemisphere, the correspon of the white matter being formed by the fimbria. At the e cornu the hippocampus is continuous with the uncus.

Fig. 302.

Fig. 302.—LOWER AND BACK PA CEREBRUM OF THE LEFT SIDE, S POSTERIOR AND DESCENDING COR LATERAL VENTRICLE OPENED (a Hirschfeld and Leveillé). ½

1, Apex of temporo-sphenoidal l cinate convolution; 2, cut surface bral hemisphere; 3, point of t cornu of the lateral ventricle; 3' collateralis; 4, cut surface of the back part of the corpus callosum the middle; 4', placed on the exte corpus callosum into the cerebral points by a line to the hippocamp the posterior cornu; 5, cut edge of pillar of the fornix passing down a hippocampus major and fimbria; 6 the hippocampus major points to 6', pes hippocampi; 7, fascia dentat

The *posterior cornu* (fig. projects backwards into the of the posterior lobe. At its it is pointed, and directed Its outer wall is formed, like that of the descending cornu, of t fibres passing from the corpus callosum to the temporo-sphen and to the lower part of the occipital lobe. The floor is form medullary substance of the occipital lobe, covered, of course, as with the inner surface of the ventricle everywhere, by epend with epithelium. On the inner wall is a curved and pointed lo eminence, named *hippocampus minor*, *ergot*, or *calcar avis*, this is another longitudinal eminence (*bulb of the posteri* caused by the bundle of fibres which form the forceps maj round from the splenium of the corpus callosum to enter th lobe. At the junction of the posterior with the descendi between the hippocampus major and minor, is a smooth named *eminentia collateralis*, or *pes accessorius*, which may ex way down the descending cornu behind the great hippocampus

The calcar avis or hippocampus minor is the convex side of

al substance which forms the calcarine sulcus, and in like manner minentia collateralis corresponds with the collateral sulcus.

hippocampus minor is not peculiar to the human brain as was at one time t, but is found in the brains of quadrumana. In the human subject the or cornu varies greatly in size, and the hippocampus minor is still more le in its development, being sometimes scarcely to be recognised, and at proportionally large. It is usually most developed where the posterior cornu gest; but the length of the posterior cornu, and prominence of the hippo- minor, are by no means in proportion to the dimensions of the hemisphere. ther seem to be associated with thinness of both the medullary and the al substance.

posterior cornu is curved round the internal parieto-occipital fissure, which thus be regarded as causing a projection in the wall of the ventricle.

The septum lucidum is a thin double partition, placed between two lateral ventricles. It is double, being composed of two distinct inæ, having an interval between them, which contains fluid. This rval is the *fifth ventricle*, *ventricle of the septum*, or *Sylvian ventricle* . 801, between *e* and *f*. It extends vertically between the corpus sum above and in front, and the anterior part of the fornix below l behind (fig. 258); and as the latter gradually sinks down from the pus callosum, the septum with its contained cavity is deep before and row behind, in form somewhat resembling an obovate leaf. Posteriorly it is bounded by the pillars of the fornix (fig. 307) and by the ina cinerea.

he laminæ of the septum are formed of a part of the median wall of the hemi- res which has remained free, while the surrounding parts have become united the development of the corpus callosum above and in front and the fornix ow and behind. The ventricle of the septum was therefore originally a part the great longitudinal fissure, and has no connection with the internal tricular cavity of the brain. Accordingly we find that it is not lined by thelium, but each lamina consists of a thin layer of grey matter next the ity, and homologous with the grey matter of the cerebral cortex, and a ker layer of white matter continuous below on either side with the general ite matter of the hemisphere. Externally, next the lateral ventricle, is a layer ependyma, and covering this the epithelium which lines the lateral ventricle.

The **fornix** (fig. 301, *f* is an arched longitudinal white commissure, margin of which is seen in the floor of the lateral ventricle. It con- s of two lateral halves, which are separated from each other in front l behind, but in the intermediate part are joined together in the mesial ne. The two parts in front form the *anterior pillars*, or *columns*, of fornix; the middle conjoined part is named the *body*; and the hind s, which are again separated from each other, form the *posterior rs* or *crura*.

The *body* of the fornix is triangular in shape, being broad and flat- d behind, where it is connected with the under surface of the corpus sum, and narrower in front, where it is connected to the septum dum. Its lateral edges are free and are in contact with the choroid uses of the lateral ventricles, and its under surface rests upon the m interpositum, which separates it from the optic thalami and the d ventricle (see fig. 291 on p. 325).

The *anterior pillars* or *columns* of the fornix (fig. 305, *Cf*), cylindrical form, can be traced downwards, slightly separated from each other, ough the grey matter on the sides of the third ventricle, in front of the

foramina of Monro, of which they form the anterior boundaries, backwards to the corpora albicantia. There each column tu itself, making a twisted loop which forms the white portion of t albicans, and from this it can be traced (as the bundle of Vicq upwards into the anterior nucleus of the optic thalamus (fig. 30 pillar is connected near the foramen of Monro with the pe the pineal gland, and with the tænia semicircularis, and receives fibres from the septum lucidum.

According to Gudden and Forel the fibres of the anterior pillars in the grey matter of the corpora albicantia, and are not directly con in dissected preparations they seem to be, with the bundle of Vicq d'A

Fig. 303.

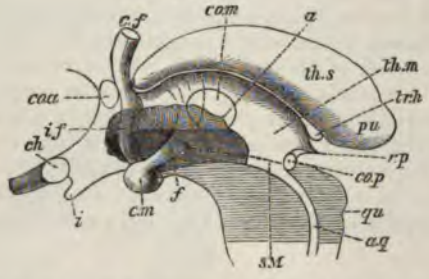


Fig. 303.—SKETCH SH ORIGIN AND CONN THE ANTERIOR PILL FORNIX (Schwalbe).

A median section made through the thir and the superficial g removed at its anterio part. *th.s*, upper p thalamus; *th.m*, its face: between the t medullary stria, leadin pineal gland and trigo nulæ, *tr.h*, to the ant of the fornix, *c.f*; *f*, Vicq-d'Azyr; *c.m*, corpus mammillare; *i.f*, fibres of the inferior pedun thalamus diverging in its substance; *co.a*, anterior commissure; *co.m*, m missure; *ch*, chiasma; *i*, infundibulum; *r.p*, stalk of pineal body; *qu*, corp gemina; *aq.*, aqueduct.

The *posterior pillars* or *crura* of the fornix (fig. 301, *o*) are th ing posterior prolongations of the two flat lateral bands compo body. At first they adhere to the under surface of the corpus then, curving outwards and downwards over the pulvinar of the lamus, each crus enters the descending cornu of the lateral where part of its fibres are distributed on the surface of the gre campus and the remainder are prolonged as the narrow band matter known as the *tænia hippocampi* or *fimbria* (fig. 30 relation of which to the fascia dentata and hippocampus has bee alluded to (see p. 346).

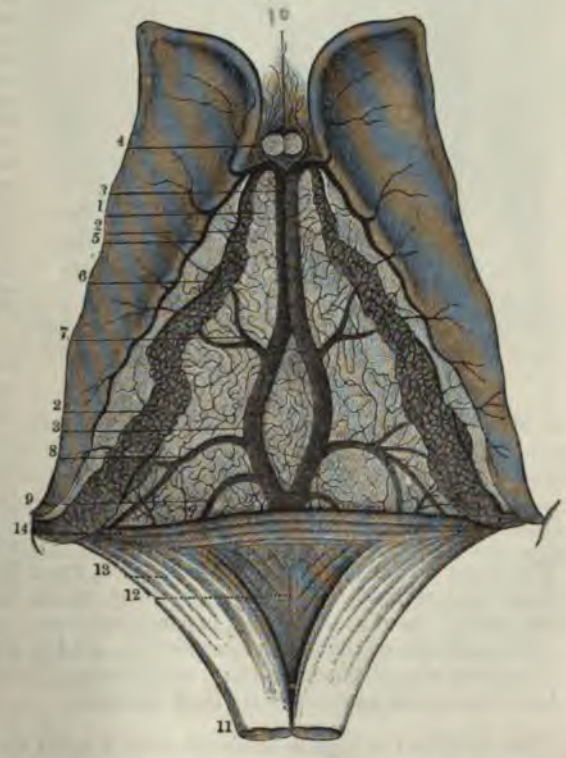
On examining the under surface of the fornix and corpus there is seen posteriorly the thickened border or splenium of and in front of it the diverging halves of the fornix, betwee triangular portion of the corpus callosum appears, marked w verse, longitudinal, and oblique lines. To this part the term been applied (fig. 304, 12).

The **foramen of Monro** is an interval on each side be anterior pillar of the fornix and the anterior part of the optic This interval leads from the third ventricle to the lateral The openings of opposite sides, passing downwards and backwa in the middle line below, and thus is produced a passage, sing but dividing into two branches above, somewhat like the lett forming a communication between the third ventricle and bo ventricles. This passage is named the *foramen commune anter*

nsverse fissure of the cerebrum is the name given to the cleft-like hich is made into the ventricles when the choroid plexuses of the pia ich invaginate the thin epithelial wall of the ventricles, are pulled away, rith them the epithelium which is reflected over them from that lining cle. Its extent may be made manifest after the lateral ventricles have ed, by completely dividing the fornix and corpus callosum in the e, and raising the divided parts from the undisturbed velum interpo- w. It will then be found that the posterior and middle portions of the nding the hippocampus major and fimbria, may, by rupture of the thin which is prolonged from the fimbria to the choroid plexus, be sepa- n the subjacent anterior parts. The transverse fissure which is thus produced extends from the extremity of the descending cornu on one the optic thalami, third ventricle, and mesencephalon, to the extremity scending cornu of the other side. It is bounded above by the corpus and fornix in the middle, and on each side by a free margin of the e formed by the fascia dentata and fimbria: inferiorly it is bounded middle line by the corpora quadrigemina, and on each side by the part of the optic thalamus.

elum interpositum or **tela choroidea** (fig. 291, *v.i.*, fig. 304) ongation of the pia mater over the third ventricle and optic and its more highly vascular free borders, projecting into the

Fig. 304.



—VIEW OF ER SURFACE VELUM IN- UM, CHO- XUSES, AND STRIATA ppey after zyr). ⅔

art of the ea or velum n; 2, cho- s; 3, left len partly the right; eins from f the cor- m and the cidum; 5, the corpus 6, convolu- al vein of d plexus; sing from us opticus striatum; proceeding ferior cornu ampus ma- from the ornu; 10, llars of the led in front ramen of 11, fornix ar its mid- rned back- lyra; 13, r pillar of ; 14, the splenium of the corpus callosum.

lateral ventricles, form the choroid plexuses of those ventricles. It nearly corresponds in extent with the fornix, which rests upon its upper surface.

The *choroid plexuses of the lateral ventricles* (fig. 301, *c* ; fig. 304, 2, 2) extend from the foramen of Monro, to the point of each descending

Fig. 305.

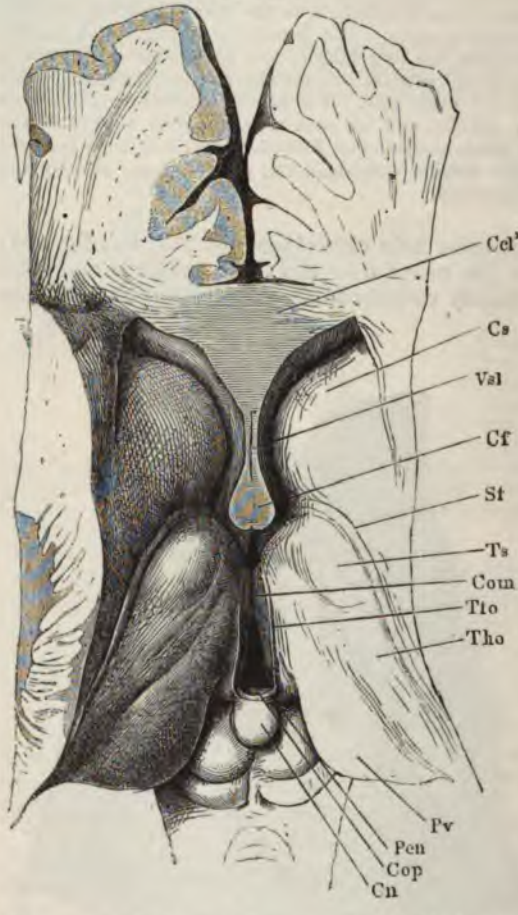


Fig. 305. — VIEW FROM ABOVE OF THE THIRD VENTRICLE AND A PART OF THE LATERAL VENTRICLES (Henle).

The brain has been cut horizontally immediately below the corpus callosum, and the fornix and velum interpositum have been removed.

Tho, thalamus opticus; *Ts*, its anterior tubercle; *Pv*, pulvinar; *Com*, middle commissure stretching between the two optic thalami across the middle of the third ventricle; *Cf*, columns of the fornix; *Cp*, pineal gland projecting downwards and backwards between the superior corpora quadrigemina; *St*, stria terminalis; *Cs*, nucleus caudatus of the corpus striatum; *Vl*, ventricle of the septum lucidum; *Ccl*², section of the genu of the corpus callosum; *Pen*, commencement of the pedunculi cerebri or peduncle, *Tto*; *Cop*, posterior commissure.

cornu. Like the choroid plexuses of the 4th and 3rd ventricles these also are highly vascular and their ventricular surface is beset with villus-like projections. The more obvious villi are again divided upon their surfaces and at their borders into small processes along which fine vessels run, and the epithelium of the ventricles is continued over their surface.

On each side of the velum interpositum, are two slight vascular fringes which run along its under surface, and diverging from each other behind, form the *choroid plexuses of the third ventricle.*

The epithelium changes its character where it covers the plexuses. It is there composed of large spheroidal corpuscles, in each of which is seen, besides a *distinct* nucleus, several yellowish granules, and one or more dark round oil-

ccording to Henle each of these cells is provided with short acumi-esses.

horoid artery enters the velum interpositum at the lower end of nding cornu ; and other arteries enter from behind, beneath the llosum. The greater number of the veins terminate in two l vessels named the veins of Galen, which run backwards on n interpositum, and passing out beneath the corpus callosum ir blood into the straight sinus, having generally first united ngle trunk.

orpora striata (*ganglia of the cerebral hemispheres*), situated in d to the outer side of the optic thalami, are two large ovoid

Fig. 306.

. — TRANS-SECTION H THE BRAIN KULL MADE ROZEN (Key zius). ½

orpus callo- w its middle eptum luci- below that ornix ; *LV*, ntricle ; *th*, between the ni the third seen ; below mus is the innominata ; ular nucleus us striatum ; nucleus of between *th* the internal utside *str* is rey band of rum, and out- gain the island of Reil at the bottom of the Sylvian fissure ; *n*, *a*, nucleus ; immediately within this is the optic tract seen in section ; *p*, pituitary , body of the sphenoid bone ; *sa*, subarachnoid space ; *v*, villi of the

f grey matter, the greater part of each of which is embedded in e substance of the hemisphere (extraventricular portion), whilst ecomes visible in the body and anterior cornu of the lateral (intraventricular portion).

ntraventricular portion of the corpus striatum (**nucleus caudatus**) , *Cs*) is of pyriform shape, its larger end being turned forwards earing in the floor of the anterior cornu, and at one part reach- outer margin of the ventricle. Its narrow end is prolonged back- nd outwards along the body of the ventricle and into the roof of ending cornu, passing nearly to the extremity of the latter. On into it, there may be seen at some depth from the surface of white fibres which are prolonged through it from the inner and give it the streaked appearance from which the name triatum has been derived.

xtraventricular portion of the corpus striatum (**nucleus lenticu-**

laris) is separated from the intraventricular part by a layer o substance (*internal capsule*), but this is bridged across in front b of grey matter. The lenticular nucleus is only seen on section hemisphere. Its horizontal section (fig. 307, *n.l*) somewhat re

Fig. 307.

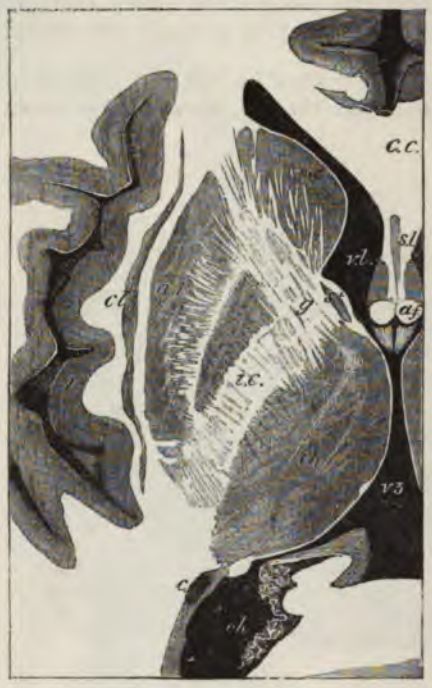


Fig. 307. — HORIZONTAL THROUGH PART OF THE HEMISPHERE (E. A. S., aft paration by Mr. Shattock). size.

The section is viewed fro *v. l*, lateral ventricle, cornu; *c. c*, corpus callos septum lucidum; *a. f*, ant lars of the fornix; *v* 3, t tricle; *th*, thalamus opti stria terminalis; *n. c*, caudatus, and *n. l*, nucl cularis of the corpus striat internal capsule; *g*, its angle *c*, tail of the nucleus caud pearing in the descending the lateral ventricle; *cl*, cl *I*, island of Reil.

that of a biconvex lens wider in the centre t either end. The ante terior diameter corr closely with that o island of Reil, and the g width is opposite the a edge of the optic th On a transverse vertic tion through the midd 306, *str*), this nucleus triangular, and two whi (medullary laminæ), to the outer side, divide it into three zones, of which the oute largest and of a dark reddish colour marked with fine white striæ the inner two are more yellowish in tint. On its outer side is a grey termed the *claustrum*, which is separated from the lenticular nucl stratum of white substance named the *external capsule*. The inner or radiation of the crusta, separates it in the greater part of its exte the caudate nucleus and thalamus, but anteriorly the two nuclei corpus striatum are united at their bases, and posteriorly the le nucleus is continuous below with the superficial grey matter form anterior perforated lamina, with which the claustrum is also con

The **claustrum** (figs. 291, 307, *cl*) is a thin lamina of grey which is smooth next the outer capsule but ridged and furro ternally, the ridges and furrows corresponding to the gyri and the central lobe, with the white substance of which the claustru immediate relation. According to Meynert the claustrum is to b upon as a separated part of the grey cortex of the central lobe.

Along the inner border of the nucleus caudatus, in a depression it and the optic thalamus, is seen a narrow whitish semitranspare already noticed in the description of the ventricle, named **tænia s**

ris or **stria terminalis** (fig. 305, *Sf*), which is continued backwards the white substance of the roof of the descending cornu. In front e it is largest it reaches the corresponding anterior pillar of the fornix, which it comes into connection; at its other end it enters the nucleus dalæ in the inferior cornu.

ie **nucleus amygdalæ** is a rounded mass of yellowish grey matter, nuous with the superficial grey matter of the apex of the temporo- oidal lobe, forming a projection at the end of the descending of the lateral ventricle. It is situated below the anterior part of enticular nucleus (fig. 306, *n.a*).

ie **anterior commissure** appears in the anterior part of the third icle as a round bundle of white fibres, immediately in front of the ior pillars of the fornix, and crossing between the corpora striata; bres extend laterally below the lenticular nuclei of the corpora a, and then pass outwards and backwards in a curved course as a what twisted longitudinal bundle which spreads out in the central of the hemisphere, and is traceable to the medullary substance of emporo-sphenoidal lobe above the descending cornu of the lateral icle and eventually to the nucleus amygdalæ (Ferrier).

animals in which the olfactory lobe is well developed the anterior fibres of commissure appear to be connected with the base of that lobe, and it is ght that in this way a communication is established between the temporo- oidal lobe (and nucleus amygdalæ) of the one side and the olfactory lobe nerves of the other side.

e anterior commissure is the first transverse commissure of the cerebrum to veloped in the embryo; it is also the most constant in the animal series.

MINUTE STRUCTURE OF THE GANGLIA OF THE CEREBRAL HEMISPHERES.

ucleus caudatus.—Where it lies in the lateral ventricle the nucleus caudatus vered by a layer of ependyma and over this by the ciliated ventricular elium. The ganglion is itself composed of a reddish grey substance like that ie outer zone of the lenticular nucleus. On the deeper side, that turned rds the inner capsule, the nucleus receives from this, as before mentioned, mber of bundles of medullated fibres. According to the account given by ert, the bundles pass in both directions, some serving to connect the gang- with the peduncle of the cerebrum, others to connect it with the cortex ri. On the other hand, according to Wernicke it is doubtful if any of pass to the white matter of the hemispheres, nor do they come from the directly, but only after traversing the medullary laminæ of the lenticular us.

nerve-cells of the nucleus caudatus are multipolar, and both moderately large mall. In addition, peculiar spheroidal cells containing two or more nuclei scribed by Henle. The connection of the cells with nerve-fibres, although bly existing, has not hitherto been demonstrated.

cleus lenticularis.—All three zones of the nucleus are pervaded by bundles ite fibres, but they are most conspicuous in the outer zone. The grey r between the fibres contains many cells with yellow pigment in them. pass directly into the inner zone from the adjacent part of the inner le (*i. e.* from the peduncle of the cerebrum), while others from the mesial f the peduncle, passing through the substantia innominata below the optic nus, curve outwards below the lenticular nucleus as a distinct bundle (ansa ularis) and entering its medullary laminæ are distributed in the middle and zones. According to Meynert if these fibres are traced downwards in the cle they are soon found to cross to the other side below the third ventricle ass to the nuclei of the third and fourth nerves.

er fibres connect the caudate with the lenticular nucleus, and others pass

from this nucleus into the corona radiata or white substance of the hemisphe and thence to the cortex.

The outer capsule is formed of fibres which are not directly connected wi the lenticular nucleus but are derived partly from the anterior commissure, a in part from a portion of the ansa lenticularis.

In the **claustrum** the cells are for the most part small and spindle-shaped, a arranged parallel with the surface, resembling those which are met with in t deepest layer of the grey cortex of the hemispheres. Most of the cells cont yellow pigment.

INTIMATE STRUCTURE OF THE CEREBRAL HEMISPHERES.

The cerebral hemispheres, like the rest of the encephalon, a composed of white and grey substance, the white pervading nearly th whole of the middle of each hemisphere, where it forms what is know as the *medullary centre*, and extending into the convolutions; the gr forming a covering of some thickness over the whole surface of the co volutions (*cortex*), and occurring also at the base of the hemisphere in th form of the ganglia which have just been described.

THE WHITE MATTER consists of medullated fibres, varying in size i different parts, but in general still smaller than those of the cord and me dulla. They are arranged in flattened bundles separated by neuroglia; the bundles have a somewhat rod-like appearance in transverse section.

The general direction which the fibres follow is best seen in a brain that has been hardened by immersion in alcohol or some other medium, although in an ordinary dissection of such hardened brains with the scalpel, we do not then trace the single fibres, but only the smaller bundles and lamellæ which they form by their aggregation. It must also be admitted that where they intimately decussate, the tearing of fibres across is liable to be mistaken for the separation of sets of fibres one from the other; it is necessary to correct such errors by the examination of sections under the microscope.

The fibres of the medullary centre, though forming many different groups, may be referred to three principal systems, according to the general course which they take, viz.:—1. *Ascending* or *peduncular fibres*, which pass from the isthmus encephali to the hemispheres. These fibres increase in number as they ascend through the isthmus, and still further in passing the optic thalami and corpora striata, beyond which they spread in all directions into the hemispheres. 2. *Transverse* or *commissural* fibres, which connect the two hemispheres together. 3. *Longitudinal* or *collateral* fibres (the association-fibres of Meynert), which, keeping on the same side of the middle line, connect near or distant parts of the same hemisphere.

1. The **peduncular fibres** in each hemisphere are derived in part directly from the fibres of the crusta, in part from the tegmentum, probably indirectly through the optic thalamus; and according to most observers they are reinforced as they pass the corpus striatum by fibres derived from the nuclei of that body.

a. Those fibres which are derived directly from the crusta pass between the optic thalamus and nucleus caudatus and the nucleus lenticularis in the inner capsule, probably giving off fibres from this to those ganglia, and on the other hand being here joined by fibres which issue from them. Beyond the inner capsule the fibres diverge into the general white matter of the hemispheres, forming part of the system of radiating fibres known from its fan-like arrangement as the *corona radiata* (Reil) or *fibrous cor*

ayo), the latter term being derived from the way in which the mblage of radiating fibres is curved round in the form of an mplete hollow cone as it emerges from below the nucleus caudatus, h follows the curve of the lateral ventricle.

lthough it is probable that many of the fibres of the crusta pass tly into the medullary centre and through this to the grey cortex, out entering the basal ganglia of the hemispheres, this has only definitely ascertained for one or two of the tracts of fibres which in the crusta. The best known of these is the *pyramidal tract*, h, according to the observations of Charcot, Ferrier, and Flechsig, raceable through a part of the inner capsule (opposite the lle of the thalamus) and corona radiata to the grey cortex of the ading frontal and ascending parietal convolutions and the parts in neighbourhood of these. This is of interest in connection with the that physiological experiment indicates the grey matter of these icular convolutions as especially concerned in governing the action ie chief groups of muscles of the body (motor-centres of Fritsch and ig, and of Ferrier).

nother group of fibres which is traceable directly to the convolutions ie so-called *direct sensory tract* which passes from the external or al part of the crusta into the white matter of the occipital lobe of hemisphere.

few of the fibres of the crusta (those nearest the inner or mesial) do not pass into the inner capsule and corona radiata but are col- ed into the bundle known as *ansa lenticularis* and pass outwards erneath the thalamus into the nucleus lenticularis (see p. 353).

. *The fibres which pass towards the cerebrum in the tegmentum*, are inally constituted by the longitudinal bundles of the formatio reticu- s of the medulla oblongata. They are reinforced as they pass upwards ets of fibres derived from the superior peduncle of the cerebellum, and aps the middle peduncle according to Meynert and Broadbent; pro- ly also from the corpora quadrigemina, and from the nerve- and other lei in the parts which they traverse. They become lost for the most in the subthalamic tegmental region and in the thalamus, but on the r hand, from the outer side of the thalamus fibres stream outwards (see 24), and joining the general system of the corona radiata, diverge to ly every part of the hemisphere, but especially to the temporo-sphe- al and occipital lobes, the parts which experiment seems to indicate as g especially concerned with the functions of the special sense-organs. r fibres, apparently continuous with this same system, pass from the erior part of the thalamus into the optic tract.

om the lower part of the thalamus anteriorly fibres emerge forming undle known as the inferior peduncle of the thalamus, and curving d below the nucleus lenticularis, pass into the white substance of sland of Reil (see p. 325).

The **transverse** or **commissural fibres** which connect the spheres together include *a. The transverse fibres of the corpus cal-* (p. 342). *b. The fibres of the anterior commissure* (p. 353).

course of these fibres has already been described at the places indicated. bres of the posterior commissure (p. 321) are sometimes regarded as con- g the posterior parts of the hemispheres.

The **longitudinal or collateral fibres** include those of *a.* the

fornix, *b*. the *tænia semicircularis*, and *c*. the *striæ longitudinales* *corpus callosum*, already sufficiently noticed; and likewise the follo

d. Fibres of the gyrus fornicatus; fillet of the corpus callosum (*cingulum*.—These fibres constitute the white substance of th fornicatus, and take a longitudinal course immediately above th verse fibres of the corpus callosum. In front they bend do within the gyrus to which they belong, and are connected anterior perforated space, being joined by certain longitudi which run along the under surface of the corpus callosum near th line. Behind, they turn round the back of the corpus callosum a descend to the point of the temporo-sphenoidal lobe, where, acc Foville, they again reach the perforated space. Offsets from th pass upwards and backwards into the secondary convolution from the gyrus fornicatus in the longitudinal fissure.

e. Uncinate or arcuate fasciculus.—Under this name is de white bundle, seen on the lower aspect of the hemisphere, passi the bottom of the Sylvian fissure, and connecting the frontal temporo-sphenoidal lobe. The fibres of this bundle expand at tremity, and the more superficial of them are curved or hooke between the contiguous parts of the two lobes,—from whic stance it has derived its name.

f. Inferior longitudinal fasciculus.—This is a bundle of fib lies close to the outer wall of the posterior and inferior corn lateral ventricle and connects the temporo-sphenoidal and occip

g. Association-fibres.—The convolutions of the cerebrum are c with each other by white fibres, which lie immediately beneath th substance. Some of them pass across the bottom of the sulci adjacent convolutions; whilst others, which are longer and ru connect convolutions situated at a greater distance from one an

THE GREY MATTER ON THE CONVOLUTED SURFACE of the forms a continuous layer indistinctly divided into two or three interposed thin layers of paler substance.

In examining a section macroscopically from without inwards (fig. 3 meet with—1. A thin coating of white matter situated on the surfa on a section appears as a faint white line, bounding the grey surface This superficial white layer is not equally thick over all parts of tical substance, but becomes thicker as it approaches the borders of voluted surface; it is accordingly less conspicuous on the lateral con of the hemispheres, and more so on the convolutions situated in the lo fissure which approach the white surface of the corpus callosum, and the under surface of the brain. It is especially well marked on the sphenoidal lobe, near the descending cornu of the lateral ventricle, convoluted surface is bounded by the fimbria, and it has been there under the name of the *reticulated white substance*. 2. Immediately b white layer just described, is found a layer of grey or reddish grey colour of which, as indeed of the grey substance generally, is deeper according as its very numerous vessels contain much or little blood. 3. pearing in section as a thin whitish line (line of Vicq d'Azyr, outer line of 4. A second grey stratum. 5. A second thin whitish layer (inner li larger). 6. A yellowish grey layer which lies next to the central whit the convolution. In some convolutions, especially those bordering on th fissure, the line of Vicq d'Azyr is very distinct but the inner line of is not visible (fig. 308, 2).

This grey substance of the convolutions contains cells a

ed in neuroglia, with numerous blood-vessels, which pass vertically
at the surface but in the deeper parts are more irregularly
d.

cells are of various forms and sizes, many of them with numerous
s. Some of these branching cells are irregular in form and posi-
t the majority are more regularly pyramidal in shape, with the
the pyramid turned towards the surface of the convolution. The
size of the larger pyramidal cells is $\frac{1}{1800}$th of an inch in dia-
t the base, and each has a rounded nucleus having an average
r of $\frac{1}{3500}$th of an inch. They generally contain a little yellowish
t. The cells often appear to lie in distinct cavities in the grey
(pericellular spaces), but it is uncertain if these are natural or

Fig. 308.

2 1

—SECTIONS OF CEREBRAL CONVOLUTIONS (after Baillarger).

rts are nearly of the natural size.
the six layers ordinarily seen
erebral cortex when carefully
with the naked eye; 2, the
e of a section of a convolution
neighbourhood of the calcarine

d by shrinking after death. The process from the apex of each
y be traced for some distance towards the surface of the con-
giving off one or two branches as it passes outwards. The
f termination of these branches is unknown. Several fine
ng processes pass from the angles at the base of the cell and
wards or towards the medullary centre. Some of these pro-
ivide and ramify, the branches forming a network of fine anasto-
fibres, while others have been traced inwards undivided, and
cess at least from each cell is probably continuous with the axis-
of a nerve-fibre. The undivided axis-cylinder process, according
observers, arises from the centre of the base of the cell. The
s of these cells, as well as the body of the cell itself, possess a
longitudinal striation. The smaller angular corpuscles are also
l with branches which run in various directions, and probably
to a fine network. Rounded cells, tolerably uniform in size
$\frac{1}{500}$th of an inch in diameter), and having no visible processes
ur.

ibres radiate from the white centre of each convolution in all
ns into the grey cortex, having a course for the most part
icular to the free surface. In passing through the grey sub-
hey are arranged in bundles about $\frac{1}{1500}$th of an inch in diameter,
s separate the nerve-cells into elongated groups, and give the
a columnar appearance. The direction of the fibres varies
g to the part of the convolution in which they occur, whether
summit or the base, and the radiating direction is somewhat
he sulci between the convolutions, where the arched fibres which
the adjacent convolutions seem to obscure the radiating bundles.
bres pass in various directions through the grey substance, con-
its several layers. Gerlach describes bundles of medullated fibres
angles to the *radiating bundles, and forming* with them a large-

Fig. 309.

meshed network, in
stices of which is a
network, composed
non-medullated ne
and formed, he bel

Fig. 309.—Section
convolution (M

1, Superficial layer
corpuscles; 2, layer
midal corpuscles; 3, b
pyramidal corpuscles,
columns by the radiatin
4, narrow layer of s
corpuscles; 5, layer o
irregular cells in medu

the grey substanc
by the interlacem
astomosis of the
processes from
cells.

**Layers of ce
cortex.**—The fo
rangement of the
different depths o
tion, and in this
layers are distingui
more or less defi
ters, but not sha
off from one ano
relation to the
distinguishable by
eye is not clearl
The most commo
which is seen in
tions of the parie
this most observe
Meynert in recc
layers as follows

1. The most e
is narrow, and
$\frac{1}{10}$th of the whol
the grey cortex.
posed chiefly of n
contains a few
with fine proces
not of nervou
(Bevan-Lewis an
A few medullate
occur in it, fo
superficial white
mediately under
mater.

next layer, of nearly the same thickness, is characterized by a large number of small nerve-cells, mostly pyramidal, with processes.

hird layer is of paler tint and much greater thickness. It ramidal branching cells, large and small, arranged as above with the pointed extremities towards the surface of the convo- separated into groups by the bundles of radiating nerve-fibres. ortion of the layer, in which the cells are larger and the separa- oups more distinct, is sometimes described as a separate layer.

ourth layer is narrower, and contains many small, irregularly- uscles, round or angular, with fine processes, placed irregularly stinctly separated into groups.

ifth layer, of greater width than the last, and blending more it, is composed of fusiform and irregular cells. The fusiform have a definite arrangement, being placed for the most part t the summit of a gyrus; but in the sulci, parallel to the surface, correspond in direction to the arcuate fibres passing from one to another; they are said to be connected with these fibres.

the last layer is the medullary centre, with which it gradually he fibres of the white substance, as they radiate into the grey come finer. They terminate partly in the axis-cylinder f the pyramidal cells, partly in two plexuses of medullated lie, the one at the base of the layer of large cells or 3rd layer, between this and the layer of small pyramidal cells (2nd ese plexuses (inner and outer white plexuses of W. Krause) y the cause of the whitish lines seen with the naked eye in the grey cortex of a fresh brain.

Sylvian fissure the fusiform cells are more abundant than and from their number in the claustrum the fifth layer rmed by Meynert the "claustral formation." They are also ant in the amygdaloid nucleus, which is indeed chiefly formed ning of the deepest layer of the cerebral cortex. The cornu n the other hand is formed almost exclusively of the large corpuscles, and the layer in which these corpuscles occur r) has, in like manner, been termed the "formation of the onis."

s of structure in different parts.—Considerable variety occurs parts of the cerebral cortex in the size and regularity of shape of ls and in the relative thickness of the several layers. It is especially otice that in the region of the motor centres and particularly in the f the ascending frontal convolution, some of the deeper pyramidal y large, and are arranged in more or less defined groups or nests n their size these deeper cells are often termed the "giant-cells" of the ex, but by Lewis and H. Clarke they are named the "ganglionic cells," ibed as situated amongst the small cells of the fourth layer, which is ominated the ganglionic layer. On the other hand, in the neighbour- alcarine fissure, in the occipital lobe, large cells are very scanty, their for the most part taken by smaller ones. Again, in many parts a six- rtex is produced by the intercalation of a layer of small angular cells hird layer and the ganglionic layer (Lewis).* But the most remark-

tended account of the structure of the cerebral cortex in man and animals referred to a paper by Bevan-Lewis and H. Clarke in the "Proceedings of iety," vol. xxvii., 1878; and to papers by Bevan-Lewis, in the "Philo- actions" for 1880 *and 1882, and in "Brain,"* and by Betz in the Med. *Zt.*

able differences of structure occur at the incurved margin of the hemisphere in the region of the cornu ammonis or hippocampus major, and in the olfactory lobe. These will now be specially considered.

Fig. 310.

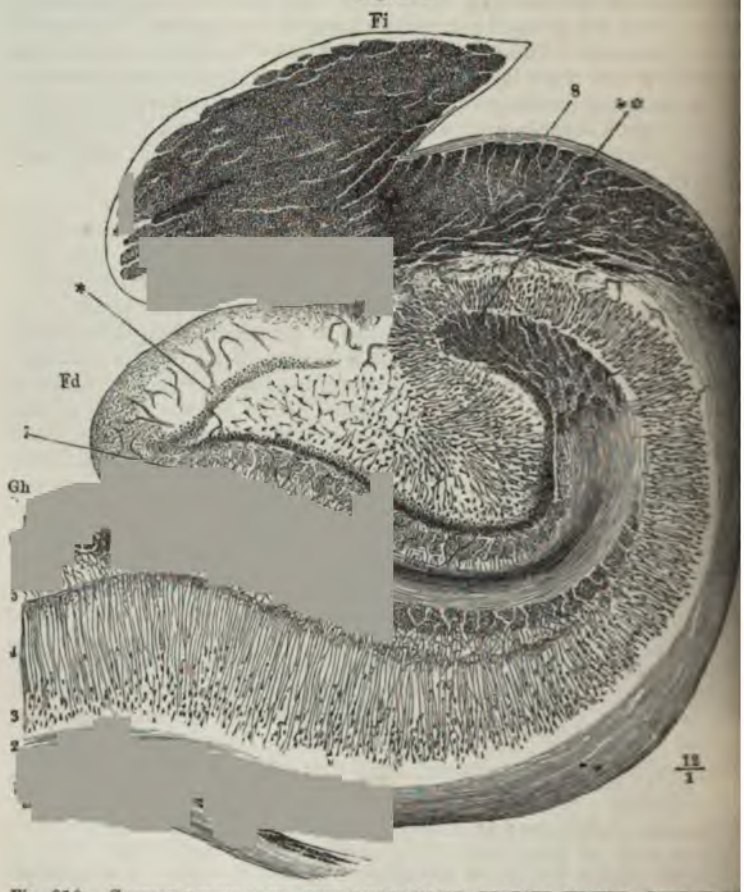


Fig. 310.—SECTION ACROSS THE HIPPOCAMPUS MAJOR, DENTATE FISSURE, DENTATE FA AND FIMBRIA (after Henle).

Gh, part of the gyrus hippocampi or uncinate convolution; *Fd*, fascia dentata dentate convolution; between them is the dentate fissure; *Fi*, fimbria, composed longitudinal fibres here cut across; 1, 2, medullary centre of the hippocampal gyrus longed around the hippocampus, *H*, as the so-called alveus, into the fimbria; 3, lay large pyramidal cells; 4, stratum radiatum; 5, stratum laciniosum; 6, superi medullary lamina, involuted around the dentate fissure; **, termination of this lam the fibres here running longitudinally; 7, superficial neuroglia of the fascia dent *, stratum granulosum.

Structure of the hippocampus major or cornu ammonis.—The hippocampus it will be remembered corresponds to the hippocampal fissure externally; fissure separating the uncinate convolution below from the fascia dentata ab The uncinate convolution (fig. 298, *b*) has the ordinary structure of the cere gyri, being composed of a superficial grey cortex and a thick white centre. grey cortex is prolonged around the hippocampal fissure, there becoming se

kened, and forming the main part of the hippocampus; the white centre olonged over the projection of the hippocampus into the ventricle, but ery thin in this situation where it is known as the *alveus*. It is covered thelium and ependyma of the ventricle.

he hippocampal fissure the grey matter of the hippocampus swells out notched lamina known as the *fascia dentata* (dentate convolution, fig. The white matter of the alveus is in like manner prolonged over this far as its free border; it becomes thickened and is continuous with band known as the *fimbria* (*Fi*).

ater part of the grey matter of the hippocampus is occupied by several olerably large pyramidal cells (fig. 310, 3) with long apical processes, embedded in a neuroglia-matrix, and confer upon this, especially in its , a striated aspect; hence the name of *stratum radiatum* is sometimes istinguish this part of the layer (4). By their bases the cells rest upon layer or alveus, into which their axis-cylinder processes pass, but there parts a thin layer of grey matter intervening.

ial to this *stratum of large pyramidal cells* and their processes, is a layer glia of which is characterized by its openly reticulate structure (*stratum* , 5). The texture is more condensed both in its superficial and in its ts, and in the latter are a number of small cells (*stratum granulosum*). sels are numerous in this part, which appears to correspond with the perficial layer of the series met with in the typical convolution. Super- again is a well-marked layer of medullated fibres continuous with the l white substance of the uncinate convolution (see p. 340). It is known *voluted medullary lamina* (fig. 310, 6), and represents an increased ent of the thin layer of white fibres which is ordinarily found next the the grey matter.

fascia dentata the large pyramidal cells are placed in the centre and are y arranged: they are surrounded by a ring of closely packed small l cells (stratum granulosum, fig. 310, *), outside which is a very broad l layer of neuroglia with a few scattered cells.

structure of the olfactory lobe.—The peculiar structure of this part ain can best be understood by a reference to its mode of development. to be formed as a hollow outgrowth from the vesicle of the cerebral re (afterwards the lateral ventricle), and in most of the lower animals it is much more developed than in man), it exhibits even in the adult a central cavity (lined with ciliated epithelium), and in some this retains

Fig. 311.

$\frac{15}{1}$

1.—Section across the middle of the olfactory tract (Henle).

al surface; *d*, dorsal ridge. From without in successively: (1) a thin superficial layer of (2) a (darkly shaded) layer of transversely- llary fibres, of very unequal thickness in arts; (3) the central grey matter projecting up rsal ridge and here and there extending to the l partially interrupting the medullary layer.

at life its connection with the lateral The walls of the hollow outgrowth hickened and differentiated into a central euroglia next the cavity, a well-marked in- e layer of white substance outside this, and ral layer of grey matter surrounding the

a man and apes the same changes occur, but the cavity becomes completely d and in its stead we find nothing but the central neuroglia, which the most part a tract flattened out laterally, and containing but few e white or medullary substance around this appears in section in the a flattened ring consisting for the most part of longitudinal white fibres. *factory tract the peripheral layer of grey matter* is very thin and incon-

spicuous, so that the white substance almost everywhere shows through except along the dorsal ridge where there is an accumulation of the grey substance, extending into and partly interrupting the medullary ring (fig. 312). In the bulb on the other hand this dorsal accumulation of grey matter is seen; but upon the ventral side of the flattened medullary ring (fig. 312, 1, 4) in place of the thin scarcely visible layer of grey substance in the corresponding situation in the tract, several complex layers are found and form the greater part of the thickness of the bulb, what was originally the central cavity being consequently now placed near the dorsal surface. These layers seen in section occur in the following order from above down (fig. 312, 4 to 8).

The *granule layer* (fig. 312, 4) lying next to the ventral surface of the

Fig. 312.

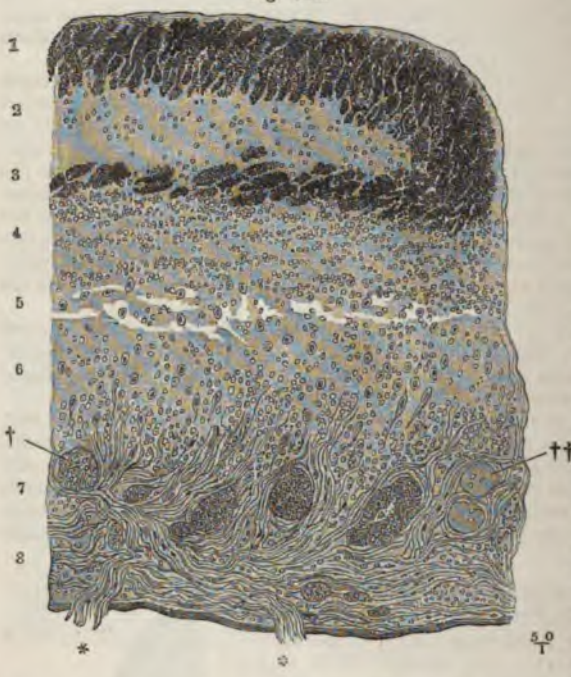


Fig. 312. — Section across a part of the olfactory bulb (Henle).

1, 3, layers of fine transverse nerve-fibres, passing round into one another at the side, and forming the flattened medullary ring, enclosing the central neuroglia 2; 4, granule-layer; 5, loose tissue with irregular spaces (lymphatic); 6, intermediate layer; 7, layer of olfactory glomeruli, †, ††; 8, layer of olfactory nerve-fibres.

lary ring, is characterised by the presence of numerous small cells, like those found in the deeper or granule layer of the grey cortex of the cerebellum. The layer is not entirely composed of these cells however, for there are present in addition a number of reticulating bundles of medullated fibres concentric for the most part with the superjacent medullary ring, and serving to separate the "granules" into groups, which occupy the meshes of the plexus formed by the nerve-bundles. Some medullated fibres also pass vertically in this layer (L. Clarke).

The *intermediate* or *nerve-cell layer* (6), which is partly marked-off from the granule layer by the presence of cleft-like lymphatic spaces (5), consists of grey or gelatinous substance (neuroglia) in which nerve-cells are embedded, having for the most part a pyramidal or conical shape, like those which characterise the grey matter of the cerebral convolutions. The largest of these cells lie next to the granule layer, where they form an almost continuous stratum, their bases being directed towards that layer, and their apices projecting downwards into the grey substance of their own layer. They appear to correspond to the stratum of large nerve-cells in the deeper part of the cortex of the cerebral hemispheres. Smaller cells lie scattered in the neuroglia, which is traversed also by numerous medullated fibres.

Layer of the olfactory glomeruli (7). The remarkable bodies which characterize this stratum were first described by Leydig in elasmobranchs and by

Stuart Clarke in mammals. They appear to consist of rounded nests of small cells probably small ganglion-cells which give origin to the fibres of the olfactory nerves. The glomeruli form an irregular layer one or two deep, and are separated from one another by bundles of non-medullated fibres which pass into the subjacent layer. Within each glomerulus, the nerve-fibres are found to form a coiled convolution amongst the cells.

Layer of olfactory nerve-fibres (8). This, the deepest layer of the bulb, consists entirely of bundles of non-medullated nerve-fibres, which become collected together into a dense plexus before sending down the branches (* *) which pass through the perforations in the cribriform plate of the ethmoid bone.

Although the whole of the olfactory tract and bulb has been generally termed by human anatomists the olfactory nerve or first pair, the facts brought to light by the study of their development, comparative anatomy, and microscopic structure clearly indicate that these parts are not homologous with the ordinary cranial and spinal nerve-roots but are in reality parts of the brain itself. It is supposed by Clarke that the layer of olfactory glomeruli is homologous with the ganglion on the posterior root of a spinal nerve.

ORIGIN OF THE CRANIAL NERVES.

In describing the origin of the cranial nerves the surface attachment or superficial origin of the roots has to be distinguished from their deep origin in the collections of nerve-cells known as the nuclei of the respective nerve-roots. Most of these nuclei have been already referred to in the description of the medulla oblongata, pons and mesencephalon, but their situation and relations may be here briefly recapitulated.

The olfactory tract and bulb (fig. 313, I) form what have usually been described as the **first** or **olfactory nerve**. As already stated they are really however a part of the cerebral hemisphere, and must be regarded as forming a distinct lobe, the *lobus olfactorius*. Their structure and attachments have already been described. The fibres which pass from the olfactory bulb through the perforations in the cribriform plate of the ethmoid bone to be distributed over the upper part of the nasal mucous membrane, collectively represent the first cranial nerve.

The **second** or **optic nerves** (fig. 313, II), which are developed as hollow outgrowths of the wall of the first primary cerebral vesicles, come off on each side from the anterior part of the chiasma, and enter the optic foramina. After curving round the crura cerebri from their origin in the geniculate bodies, the posterior part of the thalami, and the anterior quadrigeminal bodies (see p. 320 and figs. 260, 261), the optic tracts enter the chiasma at its posterior and lateral angles. In the chiasma the fibres of the tract for the most part pass diagonally across to enter the optic nerve of the opposite side, but a few fibres pass directly into the optic nerve of the same side.

In addition to the fibres which enter the optic nerves there is a small band at the posterior part of the optic tract and chiasma which simply passes across uniting the two inner geniculate bodies. This is the *inferior commissure* of Gudden. A similarly arched bundle of fibres was formerly described at the anterior margin of the chiasma, as serving to unite the retinæ of the two sides, but its existence is considered doubtful by most observers, although it has recently been affirmed by Stilling.

In all the lower vertebrates, and in many mammals, the decussation of the optic tracts is complete; that is to say, all the fibres of the optic tract of the one side (with the exception of the small inferior commissure just alluded to) pass across into the optic nerve of the same side. But, in some mammals at least, including man, there are strong reasons, chiefly derived from pathological observations, for believing *that a few of the fibres do* not thus decussate. The diffi-

culty of tracing the course of the fibres in the chiasma is very great i
quence of the fact that they take, not a straight, but a curved cours
the commissure. The fibres of the optic tract come from the anterior
geminal body through its brachium; from the inner geniculate body; f
external geniculate body and the thalamus; and lastly a few are said
into the anterior part of the tract, where this is in contact with th
cinereum, from the basal optic ganglion of Meynert (see p. 327). Accor
Stilling a bundle of fibres passes to the optic tract from the corpus subt
cum, and another bundle can be traced up to it from the pyramidal dec
in the medulla (Arch. f. micr. Anat. xviii, 1880).

The **third** or **oculomotor nerve** (fig. 313, III) arises from a col
large yellowish cells, on either side of the middle line, in the grey

Fig. 313.

Fig. 313.—Base of the brain with the origins of the cerebral nerves
Thomson). ½

This figure is taken from an adult male brain which had been hardened in alc
1, superior longitudinal fissure; 2, the olfactory tract and sulcus; 2′,
convolutions; 2″, inferior frontal convolution; 3, 3, 3, fissure of Sylvius;
temporo-sphenoidal lobe; 5, 5′, occipital lobe; 6, on the right anterior pyrami
medulla oblongata above the decussation; 7, amygdaloid lobe of the cer
8, biventral lobe; 9, slender lobe; 10, posterior inferior lobe; +, the inferi
form process; I, olfactory bulb; I′, the tract divided on the left side; II,
anterior perforated spot, marks the right optic nerve; the left has been cut sh
on the right crus cerebri, denotes the third nerve; IV, the fourth nerve; V, t
VI, on the pons Varolii, the sixth; VII, also on the pons Varolii, the facial
auditory nerve on its outer side; XI, on the cerebellum below the flocculus,
the spinal accessory nerve; between it and the auditory are seen the glosso-ph
and the vagus; XII, on the upper part of the left amygdaloid lobe, denotes th
glossal nerve; C^1, on the same, the suboccipital nerve.

Compare also figs. 260 and 261, pp. 283 and 285.

floor of the Sylvian aqueduct, in the region of the superior corpora igemina (fig. 286, B) extending as far forwards as the level of the ior commissure. Inferiorly, it is continued with scarcely any in- by the nucleus of the fourth nerve. From this column of cells the pass forwards through the tegmentum and the tegmental nucleus, artly through the substantia nigra, to emerge at the line of the motor groove on the inner surface of the crus cerebri close to the A small part of the root often emerges from between the fibres crusta, and joins the trunk of the nerve independently.

n the nucleus of the third nerve a few fibres pass towards the raphe, s to join the nerve of the opposite side, perhaps, as Meynert supposes, to pass e rectæ and enter the pyramidal tract of the other side, and to be con- l along this to the cerebrum.

e **fourth** or **trochlear nerve** arises from a nucleus which n the region between the superior and inferior quadrigeminal

Fig. 314.

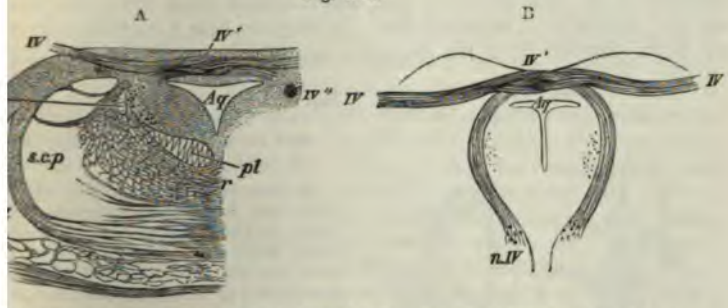


Fig. 314.—Sections through the origin of the fourth nerve (Stilling). $\frac{3}{1}$

transverse section at the place of emergence of the nerve-fibres. B, oblique section l along the course of the bundles from the nucleus of origin to the place of emer- *Aq*, Sylvian aqueduct, with its surrounding grey matter; *IV*, the nerve-bundles ing; *IV'*, decussation of the nerves of the two sides; *IV''*, a round bundle passing vards by the side of the aqueduct to emerge a little lower down; *n, IV*, nucleus of urth nerve. *l*, fillet; *s. c. p.*, superior cerebellar peduncle; *d. V.*, descending f the fifth nerve; *pl*, posterior longitudinal bundle; *r*, raphe.

es immediately below that of the third nerve. The cells are r than those of the nucleus of the third nerve. From them its s pass obliquely downwards and backwards, uniting to form one or round well-marked bundles, which run in the wall of the aqueduct ach its posterior extremity (fig. 314, *IV''*); here the fibres curve rds and pass over the commencement of the aqueduct in the anterior llary velum across to the opposite side, emerging from the velum to the middle line (fig. 287, *IV.*), and passing round the crus ri to reach the base of the brain (fig. 313, IV.).

ording to some observers the decussation of the two nerves is not complete, me of the fibres are derived from the nucleus of the same side.

ne **fifth** or **trigeminal nerve** emerges from the side of the pons lii, nearer to the upper than to the lower border (fig. 313, V.). It sts of two parts of unequal size, the smaller, motor, root being ated from the other *by a few transverse fibres* of the pons.

The **motor root** arises from a nucleus (*motor nucleus of the fifth*, fig. 273, *nv'*, fig. 316, *n V³*), which lies just below the lateral angle of the fourth ventricle, immediately in advance of the facial nucleus, and mesial to the larger sensory nucleus of the fifth. The cells of the motor nucleus are large, ramified and pigmented. The motor root, after emerging from its nucleus, passes obliquely forwards and outwards, and is joined by fibres from the so-called *descending root of the fifth* (fig. 316, B, *n V⁴*). The fibres of this arise at the side of the grey matter of the aqueduct in the region of the superior corpora quadrigemina, from some large cells which occur in the grey matter there and, increasing in number as they pass downwards form a small but distinct bundle of relatively large fibres in the lower part of the mesencephalon (fig. 314, A, *d. V*). The motor root is further joined by fibres from the raphe (see fig. 273), supposed to come either from the nucleus of the other side, or from the pyramidal tract.

The **sensory root** springs for the most part from the *superior sensory nucleus of the fifth* (fig. 315, *n V²*; fig. 273, *n v*) a collection of small nerve-cells of greater extent and less compact than the motor nucleus, on the outer side of which it lies. It receives also a considerable bundle of fibres derived from the so-called *ascending root of the fifth* (fig. 273,

Fig. 315.

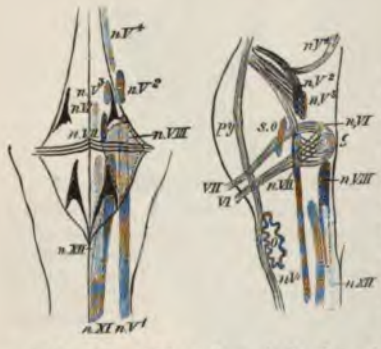


Fig. 315.—Diagrams to show the situation of the chief nerve-nuclei in the medulla and pons. Natural size. (E. A. S.)

A, from behind; B, profile view of the right half, the medulla and pons being bisected, and supposed to be transparent. The nuclei which are nearest the posterior surface in A, and the mesial plane in B are shaded more lightly; *o*, olivary nucleus; *s.o.*, superior olivary nucleus; *py*, pyramidal tract; *n V¹*, inferior nucleus and ascending root of the fifth nerve; *n V²*, superior sensory nucleus of the fifth; *n V³*, motor nucleus of the fifth; *n V⁴*, fibres of the descending root of the fifth; *n VI*, nucleus of the sixth nerve; *n VI*; *n VII*, nucleus of the facial nerve; *VII*, facial root issuing; *g*, its genu; *n VIII*, principal nucleus of the auditory nerve; *n IX*, *n X*, *n XI*, nucleus of the glossopharyngeal, vagus and spinal accessory nerves; *n XII*, nucleus of the hypoglossal.

B, *n V¹*). This is the well-marked bundle seen cut across in most sections of the medulla oblongata and pons, coursing in close contiguity with the gelatinous substance which forms the upward prolongation of the tubercle of Rolando. Its fibres are believed to arise from the nerve-cells in the gelatinous substance, which has accordingly been termed the *inferior nucleus of the fifth*. The sensory root of the fifth also receives fibres from the raphe, and others are believed to pass into it from the cerebellum.

The sensory nucleus is covered superficially by the substantia ferruginea, a collection of large deeply pigmented nerve-cells, which extends forwards in the grey matter from the superior fovea as far as the inferior corpora quadrigemina. These cells however have, so far as is known, no axis-cylinder processes, and no connection with the origin of the fifth nerve.

The **sixth** or **abducent nerve** arises from a nucleus (*nucleus of the*

e paralysis involving the internal rectus of the one side, and external
e other side, which are accompanied by atrophy of the nucleus of the
, are thus accounted for (Duval and Laborde).

venth or **facial nerve** (portio dura of the seventh pair of
ces origin in a nucleus (*nucleus of the facial*) which lies in the
eticularis at the same level as the nucleus of the sixth, but
ly placed in the substance of the pons (figs. 315, 272, *n. VII*).
end of the nucleus comes nearly in contact with the motor
the fifth, so that the two nuclei are often described as one ; its
is in a line with a collection of grey matter in the medulla known
leus ambiguus (fig. 268, *n.am.*). From its nucleus the fibres of
nerve pass backwards and inwards to the floor of the fourth
(first part of the root). Here they are collected into a
undle, oval in section, which passes for about five millimeters
in the fasciculus teres, immediately beneath the ependyma
tricle (second part of the root), and then curves outwards over
end of the nucleus of the sixth to reach its outer side. From
third or issuing part of the root makes a sharp bend (*genu*,
, *g*) and passes outwards and forwards, with a slight downward
n to appear at the lower border of the pons Varolii in a line
attachment of the fifth nerve. It emerges from the medulla
, in the outer part of the depression between the olivary body
restiform body, and is often firmly adherent, as a flattened
the lower edge and even for a short distance to the anterior
the pons. On its outer side is the auditory nerve. A separate
of the facial nerve (*pars intermedia*) is sometimes attached
nditory and facial nerves.

sses the outer side of the nucleus of the sixth, the facial root appears
fibres from that nucleus, but it is somewhat uncertain whether this is
case or not. Its fibres are reinforced by the axis-cylinder processes of
h are interpolated amongst them in the first and second parts of the
a), and also, perhaps, through the raphe from the nucleus of the
ide. According to Meynert it may be connected through the raphe

From this nucleus one (*the inferior*) of the two roots of the auditory nerve arises and, inclining outwards in front of the restiform body, reaches as it appears on the surface of the medulla, a reinforcement from the fibres of the medullary striæ which have passed over the outer side of the restiform body. It may also obtain some from the restiform body itself. It is uncertain whence the fibres of the striæ medullares are derived, but it has been conjectured that they may come from the nucleus of the opposite side through the raphe.

The *outer* or *superior auditory nucleus* (nucleus of Deiters, Laura) commences at the level of the medullary striæ where it lies between the inner nucleus and the restiform body, and extends upwards from here for some distance, becoming larger above and approaching the posterior surface of the pons near the lateral angle of the fourth ventricle. Its cells are very large, whereas those of the inner nucleus are small, and, according to Laura, they send their axis-cylinder processes towards the raphe. The nucleus is traversed by longitudinal bundles which pass to or from the cerebellum, and from these bundles as well as from the outer nucleus, the *superior root* of the auditory nerve appears to arise.

Both superior and inferior roots pass obliquely outwards and unite into a single trunk which appears at the lower edge of the pons on the outer side of and close to the facial nerve. It is also united to the lower edge of the pons opposite the inner side or middle of the restiform body from which it in part emerges. Both roots contain nerve-cells interspersed amongst their fibres, and in the inferior root these cells produce a distinct pyriform swelling. The nerve-fibres of the inferior root are much smaller than those of the superior.

In addition to the two nuclei above-mentioned there is a collection of grey matter and nerve-cells lying between the superior root and the restiform body and extending downwards into the angle between the inferior root and that body. This has received the name of *accessory auditory nucleus*. Its cells, although of small size, are peculiar in having a nucleated sheath like the cells of a ganglion. It has been supposed to give origin to the pars intermedia of the facial.

The **ninth** or **glossopharyngeal nerve** arises from a column of cells (*nucleus of the glossopharyngeal*, fig. 315, *n IX*) which is continuous behind with the nucleus of the vagus. It comes close to the surface in the inferior fovea, but in front is overlapped somewhat by the inner auditory nucleus. The fibres of the nerve pass from here outwards and forwards through the medulla to emerge by a series of five or six roots (fig. 261, *IX*), attached in a vertical line to the lateral surface of the medulla, the highest being close to the auditory nerve. The issuing fibres of the glossopharyngeal are joined by some of the fibres of the so-called solitary bundle (see below).

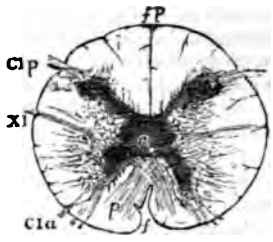
The **tenth** or **vagus** or **pneumogastric nerve** arises from the *vagus nucleus* (fig. 315, *n X*), a continuation of the glossopharyngeal nucleus above and of the accessory nucleus below. This in the open part of the medulla lies immediately external to the hypoglossal nucleus, and is marked on the surface by the triangular raised area which leads superiorly to the posterior fovea. The nucleus is partially divided into two parts by a round longitudinal bundle of fibres known as the *solitary* or *respiratory bundle* (fig. 268, *f. s.*). Of the two the outer (*n X'*) is the smaller and contains but few cells; the inner and deeper part (*n X*) contains a large number of cells, and from it more directly the roots of the nerve pass, reinforced by fibres from the solitary

ey take much the same direction through the medulla as do glossopharyngeal, many of them traversing the prolongation he gelatinous substance of Rolando; and emerge from the iedulla to the number of twelve or more, attached in a line tinuous with that of the glossopharyngeal roots.

of the solitary bundle are of large size and can be traced n the medulla and cord as far as the region of origin of the e (Krause).

ıth or spinal accessory nerve (fig. 315, *n XI*) arises e lower part of the medulla oblongata from the con- ›wnwards of the vagus nucleus, partly along the whole e cervical portion of the spinal cord—from the intermedio- and adjacent part of the anterior cornu below (fig. 316), reticular formation and base of the posterior cornu above. ormer (medullary) part which joins the vagus and is ılong with that nerve (vagal portion); the latter part on) which originates from the cervical cord is accessory to nerves and supplies the sterno-mastoid and trapezius ıe part of the vagus nucleus from which the accessory takes

Fig. 316.



TION OF UPPER END OF SPINAL CORD TION WITH THE MEDULLA OBLONGATA. art Clarke.)

fp, posterior fissure; *p*, end of decussa- s; *Cla*, *Clp*, anterior and posterior roots l nerve; *XI*, root of spinal accessory

ced immediately behind and to ıe central canal (fig. 267, *n XI*), remains closed, in a situation g to the base of the posterior e spinal cord; but where the l opens out at the point of the ›torius, the nucleus lies just at the side of the median sulcus h ventricle. The root-fibres of the vagal portion have a gh the substance of the medulla like those of the vagus, and this part of the spinal accessory resembles a separated part

It receives a few fibres from the solitary bundle. The ıs as a long series of roots the upper of which are attached f the medulla in a line with the posterior roots of the spinal , and the roots of the vagus above; while the lower emerge ıral column of the spinal cord, which they traverse in their the grey matter.

›r **hypoglossal nerve**. The *nucleus of the hypoglossal* (fig. is a column of cells nearly three-quarters of an inch long, lower part of the medulla lies antero-laterally to the central 67, *n XII*) in a situation corresponding to the base of cornu of the spinal cord; but soon after the canal has the nucleus comes nearly to the surface of the fourth ing indicated by the narrow triangular area on either side of sulcus. When viewed from the surface the grey matter of is partly concealed by transversely coursing fibres passing to The anterior end of the column is rounded, as may be seen

in longitudinal sections, and appears connected by longitudinally fibres with the nucleus of the sixth, which also lies in the f teres.

From the large multipolar cells of the nucleus most of the fib hypoglossal arise and pass outwards and forwards through the s of the medulla, to emerge by a series of fine roots at the furrow the pyramid and olive. Some fibres are said to be derived thr raphe from the nucleus of the other side.

In addition to the hypoglossal nucleus proper, a portion of grey matt as the nucleus ambiguus (fig. 268, *n.' am*), projecting into the forma laris of the lateral area of the medulla and co-extensive, according with the nucleus of the hypoglossal, is stated by that observer to through the raphe to the hypoglossal of the opposite side. On the the hypoglossal roots are said by Meynert to be reinforced by the ax processes of a group of nerve-cells (anterior or accessory nucleus of glossal) which lies a little removed from the main nucleus on the ven and is traversed by the fibres of the roots. Lastly, in common w other nerves, the hypoglossals are supposed to have a crossed communi the brain through the pyramidal tracts.

Meynert's views of the relations of the parts of the nervous To Professor Meynert of Vienna is due the credit of an attempt to the results of modern investigations into the structure and relati various parts of the central nervous system, the attempt being embo idea or scheme of the relations of the parts, which may indeed in m details have to undergo modification with the discovery of new facts, nevertheless has served and will no doubt continue to serve a useful a starting-point for renewed attempts to arrange in due order the nu complicated details which are constantly accumulating.

Meynert groups the grey substance of the central nervous system categories.

1. The superficial grey substance of the cerebral hemispheres.
2. The grey substance of the cerebral ganglia (caudate nucleus, nucleus, optic thalamus, corpora quadrigemina, locus niger, &c.).
3. The grey substance which surrounds the central cavities of the spinal cord. Commencing above at the infundibulum, it lines the thir and the aqueduct of Sylvius, extends through the fourth ventricle, and the canal of the spinal cord.
4. The cerebellum and its appendages, including the grey substa inferior medullary velum and the pons traversed by its commissural fi

If the whole tract of nervous conduction, from the grey matter of th convolutions, on the one hand, to the peripheral terminations of the sense and motion on the other, be regarded as a whole, it is seen to t second and third groups of grey substance, viz.: that of the cerebral ga that of the central grey substance. These divide it into three segments,– middle, and lower. These three segments are termed *projection-syst* the function of the whole nervous tract may be considered as being the external world on the cerebral convolutions, and conversely the c the cerebral convolutions upon the motor organs.

The *first projection system* between the convolutions and the cerebr (corpus striatum, &c.), corresponds for the most part to the corona radi

The *second projection system* connects the cerebral ganglia to the ce matter. As the latter extends from the third ventricle to the lower e spinal cord, the fibres of this system are of very various lengths.

The *third projection system*, from the grey matter of the central the muscles and terminations of the sensory nerves, corresponds nea peripheral nerves.

The other systems of fibres are (as commonly enumerated) the co such as the corpus callosum and anterior commissure, which unite

of different hemispheres, and the *association-system* of fibres which unite tical regions of the same hemisphere.

ard to the passage from the first to the second projection-system, which is to be effected in the cerebral ganglia, it should be remarked that, since it shown that the fibres of the pyramidal tract pass directly to the cerebral ithout traversing the cerebral ganglia, it is clear that an exception must for these fibres at least, if not for others. The fibres undergo conside- duction in number in passing from the first to the second system, the the crus being much fewer than those of the corona radiata. On the and, in the transition from the second to the third projection-systems, in substance of the central cavities, the fibres undergo a great increase in : the peripheral nerve-fibres being much more numerous than those of or of the cord.

ivision of the fibres of the crus into two portions, an anterior or lower), and an upper or posterior (*tegmental*), may be extended to the cerebral , in which the fibres of each portion respectively terminate above. The connected with the crusta are the lenticular nucleus, the caudate nucleus stantia nigra; or this latter may be connected with an intermediate set s belonging neither to the crustal nor to the tegmental set. They are ed (by part of the first projection-system) chiefly with the anterior part of in, and subserve for the most part voluntary motion. The ganglia of the tum are the optic thalami, corpora quadrigemina, corpora geniculata , and corpora albicantia, and subserve chiefly reflex movements.

in fibres, which are thought to be sensory, pass up from the posterior s of the cord, and form the posterior and outer fasciculi of the crusta. They rough no ganglion, but ascend behind the optic thalamus to the cortex of poral lobe.

erebellar grey substance is regarded by Meynert as forming a special organ shunted in between the cerebrum and the spinal cord and con- with the cord by the inferior peduncle, with the cerebrum by two groups of iz.:—(1). Those of the connecting arm, processus a cerebello ad cerebrum, rior peduncle, which pass from the corona radiata, under the thalamus rpora quadrigemina, to mix with the fibres of the tegmentum, and reach ebellum after a total decussation. (2). Some of the fibres of the crusta, which, are prolonged downwards through the pons, turn aside in the latter and he cerebellum through the middle peduncle. To this circumstance is due t that the size of the crusta above the pons, is much greater than that of tor tract into which it is continued below.

MEMBRANES OF THE BRAIN AND SPINAL CORD.

e cerebro-spinal axis is covered by three *membranes*, named also *ges*. They are:—1. An external fibrous membrane, named the *mater*, which lines the interior of the skull, and forms a loose sheath e spinal canal; 2. An internal areolar vascular tunic, the *pia mater*, closely covers the brain and spinal cord; and 3. An intermediate ascular membrane, the *arachnoid*, which lies over the pia mater, wo being in some places in close connection, in others separated by siderable space.

THE DURA MATER.

e dura mater is a very strong dense inelastic fibrous tunic of con- able thickness. Its inner surface, turned towards the brain and l cord, is smooth and lined with epithelium, which was formerly ded as a parietal reflection of the arachnoid membrane, this having generally looked upon as a serous membrane. The space between dura mater and arachnoid was formerly in like manner regarded as ac of the arachnoid, but is now conveniently termed the *subdural*

space. The outer surface of the dura mater is connected
surrounding parts, in a somewhat different manner in the cra
the spinal canal.

In the cranium it adheres to the inner surface of the
forms their internal periosteum. The connection betwee
depends, in a great measure, on blood-vessels and small fi
cesses, which pass from one to the other; and the dura m
detached and allowed to float in water, presents a flocculent
on its outer surface, in consequence of the torn parts proj
it. The adhesion between the membrane and the bone is mo
opposite the sutures, and also at the base of the skull, which
and perforated by numerous foramina, through which the

Fig. 317.

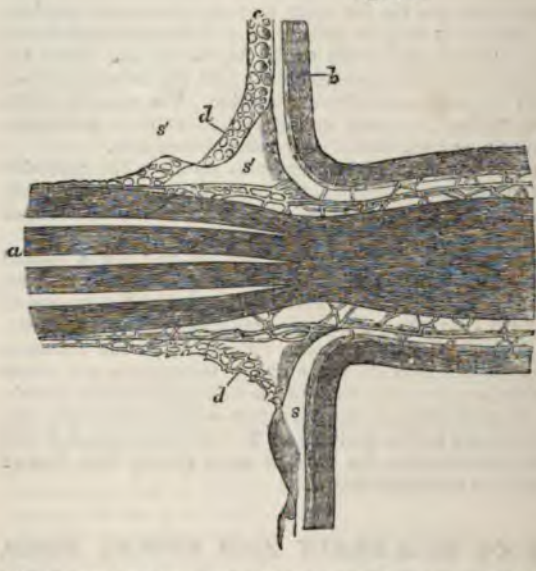


Fig. 317
THROUG
OF EXI
NERVE-
THE
(Key a
a, bun
nerve-root
lected int
dle as the
dura mat
noid; *d*,
lamella of
reflected
nerve-root
space; *s'*,
noid space

is prolon
outer su
there
with th
nium.
tissue o
mater
blended with the areolar sheath of the nerves at the foramina
exit to them.

In leaving the skull, the dura mater is intimately attach
margin of the foramen magnum; but within the vertebra
forms a loose sheath around the cord (*theca*), and is not adher
bones, which have an independent periosteum. Towards the
of the canal, a few fibrous slips proceed from the outer surf
dura mater to be fixed to the vertebræ. The space intervenin
the wall of the canal and the dura mater is occupied by lo
areolar tissue, and by a plexus of spinal veins.

Opposite each intervertebral foramen the dura-matral thec
two openings, placed side by side, which give passage to the
of the corresponding spinal nerve. It is continued as a tubula
tion on the nerve (fig. 317), and is lost in its sheath. Beside
connected with the circumference of the foramen by areolar ti

The fibrous tissue of the dura mater, especially within
is divisible into two distinct layers, and at various places

e from each other and leave intervening channels, called *sinuses*. sinuses, which have been elsewhere described, are channels for blood, and are lined with a continuation of the internal coat eins. The division into two layers is most complete at the base cull, in the middle fossa, and in the neighbourhood of the cavernous on the outer side of this the Gasserian ganglion is included the two layers. Between the two cavernous sinuses the pituitary received into a depression of the membrane, which closely sur- the organ in question, except where the infundibulum enters it. further a fissure immediately over the orifice of the acquæductus i, and here the prolongation of the membranous labyrinth of the wn as the saccus endolymphaticus, is received between the two

lura mater also sends inwards into the cavity of the skull three nembranous *processes* or *partitions* formed by duplication of its yer. Of these, one descends vertically in the median plane, and ed into the longitudinal fissure between the two hemispheres of ebrum. This is the *falx cerebri*. The second is a sloping partition, stretched across the back part of the skull, between brum and the cerebellum, named the *tentorium cerebelli*. Below other vertical partition, named *falx cerebelli*, of small extent, own between the hemispheres of the cerebellum.

falx cerebri (fig. 318, 1) is narrow in front, where it is fixed crista galli, and broader behind, where it is attached to the of the upper surface of the tentorium, along which line of ent the straight sinus is situated. Along its upper convex border, attached to the middle line of the inner surface of the cranium, e superior longitudinal sinus. Its under edge is free, and reaches n a short distance of the corpus callosum, approaching nearer hind. This border contains the inferior longitudinal sinus.

tentorium, or **tent** (fig. 318, 8), is elevated in the middle, and downwards in all directions towards its circumference, thus ig the form of the upper surface of the cerebellum. Its inner is free and concave, and leaves in front of it an oval open- rough which the isthmus encephali extends. It is attached and at the sides by its convex border to the horizontal part of the ridges of the occipital bone, and there encloses the lateral sinuses. r forward it is connected with the upper edge of the petrous portion emporal bone—the superior petrosal sinus running along this line achment. At the point of the pars petrosa, the external and l borders meet, and may be said to intersect each other—the being then continued inwards to the posterior, and the latter ds to the anterior clinoid process.

falx cerebelli (falx minor, fig. 318, 13) descends from the middle posterior border of the tentorium, with which it is connected, along rtical ridge named the internal occipital crest towards the foramen m, bifurcating there into two smaller folds. Its attachment to ny ridge marks the course of the posterior occipital sinus or sinuses.

ucture.—The dura mater consists of white fibrous and elastic arranged in bands and laminæ, those of the two layers crossing ther obliquely for the most part in the cranial dura mater. In nal dura mater the bundles have a more nearly parallel arrangement. r of flattened epitheloid cells covers its inner surface, and also its

outer surface between the places of adherence to the bones and sut
A similar layer of cells also covers both sides of the spinal
mater. The cranial membrane is traversed by numerous blood-v
which are chiefly destined for the bones, but there is a wide mesh
pillary network with peculiar ampullary enlargements, distributed ne
inner surface of the cranial dura mater. The spaces between the fi
trabeculæ contain flattened connective tissue corpuscles which frequ

Fig. 318.

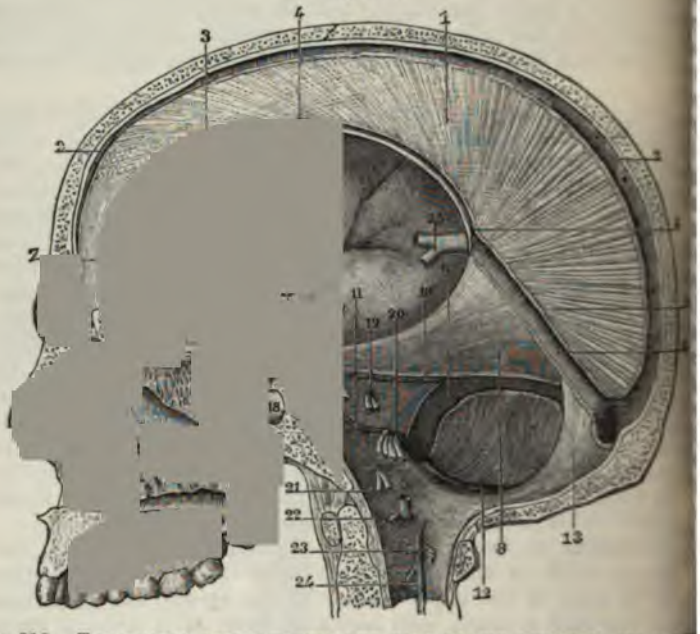


Fig. 318.—THE CRANIUM OPENED TO SHOW THE FALX OF THE CEREBRUM AND TENTO OF THE CEREBELLUM, AND THE PLACES OF EXIT OF THE CRANIAL NERVES. (Sappey).

1, falx; 2, superior longitudinal sinus; 3, concave border of the falx; 4, infe longitudinal sinus; 5, base of the falx; 6, straight sinus; 7, anterior part of the 8, right side of the tentorium cerebelli, seen from below; 9, lateral sinus; 10, supe petrosal sinus; 11, inferior petrosal sinus; 12, posterior occipital sinus; 13, falx belli; 14, 15, 16, 17, 18, second, third, fourth, fifth, and sixth cranial nerves; seventh and eighth nerves; 20, ninth, tenth, and eleventh nerves; 21, twelfth ner 22, 23, first and second cervical nerves; 24, upper end of the ligamentum denticula

have an epithelioid arrangement: these spaces, like those of connecti tissue generally, doubtless serve for the passage of lymph. They ca be injected from the epidural space where this exists, and the injecti fluid can be forced along them through the thickness of the dura mate into the subdural space. They can also be filled by inserting the i jecting cannula into the substance of the membrane. Minute n filaments, derived from the fifth and twelfth cranial nerves, an the sympathetic, enter the dura mater of the brain to be distr chiefly to the blood-vessels and to the bone, but partly perhaps to su membrane itself. Nervous filaments have likewise been traced into th dura mater of the spinal column.

THE PIA MATER.

ia mater is a delicate, fibrous, and highly vascular membrane, nmediately invests the brain and spinal cord.

the hemispheres of the brain it is applied to the entire cortical of the convolutions, and dips into all the sulci, which thus a double layer. From its internal surface numerous small ass into the substance of the brain, and hence this inner surface locculent, and is named *tomentum cerebri*. On the cerebellum a arrangement exists, but the membrane is finer, and the double r distinct in the larger sulci. The pia mater also at the trans- sure is invaginated into the lateral ventricles and over the third : (covered however by the epithelium of those cavities), and there ie velum interpositum or tela choroidea superior and choroid . It is also prolonged over the posterior wall or roof of the entricle, where it forms the so-called tela choroidea inferior and plexuses of that ventricle.

e spinal cord the pia mater has a very different character from nich it presents on the encephalon, so that it has even been d by some as a different membrane under the name *neurilemma rd*. It is thicker, firmer, less vascular, and more adherent to the it nervous matter: its greater strength is owing to an external layer, which is arranged in longitudinal glistening bundles. f this membrane dips down into the anterior fissure of the cord, res to conduct blood-vessels into that part. A thinner process nto the greater part of the posterior fissure. At the roots of the both in the spine and in the cranium, the pia mater becomes con- with their connective tissue sheaths.

pia mater of the cord is thickened by a conspicuous fibrous band, down in front over the anterior median fissure. This was by Haller *linea splendens*.

cture.—The pia mater of the cord consists of two layers, the ne being composed of interlaced bundles of connective tissue, re for the most part parallel and longitudinal, and the inner or of peculiar stiff bundles bending suddenly and enclosing some- ngular interspaces. Both surfaces of this inner layer are covered ithelioid cells, and there is a network of fine elastic fibres near faces. On the cord pigmented cells are sometimes scattered the elastic fibres. The outer and inner layers are separated here re by cleft-like lymphatic spaces communicating on the one hand e subarachnoid space and on the other with the perivascular canals ately to be mentioned. In the pia mater of the brain only the f the two layers of the pia mater of the cord is represented.

pia mater contains great numbers of blood-vessels, which sub- n it before they enter the nervous substance. In the pia mater ord they lie between its two layers, but in that of the brain on the of the membrane, either projecting freely or covered by sub- id trabeculæ. Further each vessel is enclosed by a sheath com- f a more dense arrangement of the fibres of the membrane (peri- r sheath). The diameter of the (lymphatic) canal thus formed may iderably larger than that of the contained vessel. A similar sheath, from the pia mater, accompanies the vessel into the substance rain. At its commencement it is loose and funnel-shaped and

The spinal pia mater is supplied by nerves from the sympath
The arrangement and structure of the choroid plexuses ha
been described.

THE ARACHNOID MEMBRANE.

The arachnoid is a delicate membrane which is situated o
pia mater, and invests the brain and spinal cord much less cl
that membrane. It passes over the various eminences and d
on the cerebrum and cerebellum, without dipping down into
and smaller grooves. Beneath it, between it and the pia m
space (subarachnoid space) in which is a considerable quantit
(subarachnoid fluid), and in which are seen the larger blo
passing obliquely towards the brain.

The **subarachnoid space** is larger and more evident in so
than in others. Thus, in the longitudinal fissure, the arach
not descend to the bottom, but passes across, immediately belo
of the falx, at some distance above the corpus callosum. I
terval thus left, the arteries of the corpus callosum run backwa
that body. At the base of the brain and in the spinal canal
wide interval between the arachnoid and the pia mater. In th
the brain, this subarachnoid space extends in front over the po
interpeduncular recess as far forwards as the optic nerves, and
forms a considerable interval between the cerebellum and the b
medulla oblongata (fig. 319). In the spinal canal, where it
the cord, it is of considerable extent. It is occupied, in b
and cord, by trabeculæ and thin membranous extensions of del
nective tissue, connected on the one hand with the arachnoi
the other with the pia mater. This tissue is most abunda
the space between the two membranes is least. It is den
neighbourhood of the vessels, and is continuous with the tiss
walls. In the subarachnoid space at the base of the brain
places the arachnoid is separated by larger intervals than at o
from the pia mater.

The subarachnoid space communicates with the ventric
brain by means of the foramen of Magendie (fig. 319, *f M*), th

spinal subarachnoid space (fig. 320, *k*, *l*) is divided by an imperfect septum on either side termed the ligamentum denticulatum (*g*) nterior and posterior portions. As was pointed out by Magendie also exist a sort of septum dividing the subarachnoid space at ack of the cord (*septum posticum* (*c*)), the relations of which have carefully studied by Axel Key and Retzius. It is a thin membus partition, which passes in the median plane from the pia mater ng the posterior median fissure of the cord to the opposite part of

Fig. 319.

19.—SECTION OF THE POSTERIOR AND LOWER PARTS OF THE BRAIN WITHIN THE KULL, TO EXHIBIT THE SUBARACHNOID SPACE, AND ITS RELATION TO THE VENTRI-ES. (After Key and Retzius.)

section was made in the frozen state, the cavities having been previously filled jection.

, atlas vertebra; 2, odontoid process of the axis, 2'; 3, third ventricle; 4, fourth le; *C*, *C*, corpus callosum? *C'*, gyrus fornicatus; *C*, cerebellum; *t*, tentorum; itary body; *c*, *c*, central canal of the cord; *fM*, in the cerebello-medullary part subarachnoid space, is close to the foramen of Magendie by which that space comtes with the fourth ventricle.

ose portion of the arachnoid membrane. It is most perfect in the al region, being incomplete below. It consists of numerous fine e, enclosing between them small spaces, within which run the blood-vessels. Subarachnoid trabeculæ also connect the nervewith the inner surface of the arachnoid, and in the dorsal region embranous trabeculæ extend between the posterior nerve-roots and osterior septum. In most parts however the subarachnoid nlæ are far less developed in the spinal canal than in the m.

nerves as they pass from the brain and spinal cord receive their

perineural covering from the pia mater, and, in addition, two long sheaths, an outer from the dura mater, and an inner from the arachnoid (fig. 317). Upon the optic nerve these sheaths remain distinct and separate, so that the space which each encloses may be injected, the one

Fig. 320.

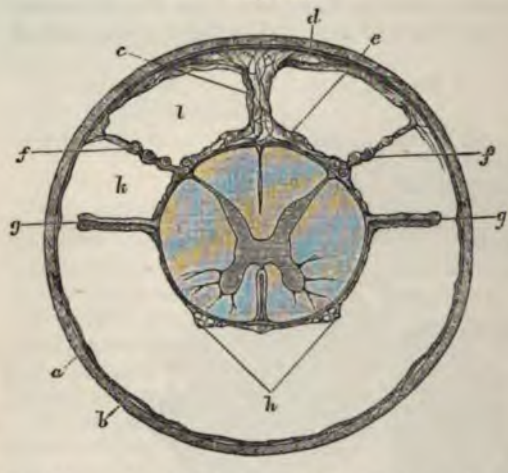


Fig. 320.—Section of the spinal cord with its membranes (upper lumbar region). (Key of Retzius). Magnified.

a, dura mater; *b*, arachnoid; *c*, septum posticum; *d*, *e*, *f*, subarachnoid trabeculæ, those at *f*, *f*, supporting bundles of a posterior nerve-root; *g*, ligamentum denticulatum; *h*, section of bundles of an anterior nerve-root; *k*, *l*, subarachnoid space.

from the subdural, the inner from the subarachnoid space. On the other nerves the arachnoidal sheath soon ceases, and the single sheath eventually blends with both the epineurium and perineurium of the nerves. Accordingly it is found that injection driven into either the subdural or the subarachnoid space passes readily along the nerves even as far as the limbs. There thus exists a continuity between the ventricles of the brain, the subarachnoid space, the perivascular canals of the cerebral substance, and the lymphatic spaces within the nerve-sheaths.

Structure.—When examined under the microscope, the arachnoid membrane is found to consist of distinct riband-like bundles of fine fibrous tissue interlaced with one another. The intervals between these bundles are filled up by delicate membranes, composed of expanded cells, the nuclei of which persist and are scattered over the structure. Several layers of this tissue, arranged in a complex way, constitute the arachnoid membrane. The subarachnoid trabeculæ consist of bundles of similar fine fibrillar tissue, each of which is surrounded by a delicate nucleated sheath, also composed of cells, and continuous with the intertrabecular cell-membranes of the arachnoid itself. The finer trabeculæ when swollen by acetic acid very frequently show the well-known ring-like constrictions. The subarachnoid membranous expansions have a similar structure. In the spinal arachnoid the fibril-bundles have for the most part a longitudinal direction.

Volkmann described a rich plexus of nerves in the arachnoid membrane of certain ruminants. Kölliker failed to detect their presence; but they have been again described by Bochdalek, who traces them to the portio minor of the fifth, the facial, and accessory nerves; and they have likewise been followed by Luschka.

Ligamentum Denticulatum.—This is a narrow fibrous band which runs along each side of the spinal cord in the subarachnoid space, between the anterior and posterior roots of the nerves, commencing above at the foramen magnum,

reaching down to the lower pointed end of the cord (fig. 244, 9, and fig. 9). By its inner edge this band is connected with the pia mater of the cord, its outer margin is widely denticulated; its denticulations are attached by points to the inner surface of the dura mater, and thus serve to support the along the sides, and to maintain it in the middle of the cavity. The first highest denticulation is fixed opposite the margin of the foramen magnum, tween the vertebral artery and the hypoglossal nerve; the others follow in ler, alternating with the successive pairs of spinal nerves. In all, there are out twenty-one of these points of insertion, but the lower six or seven are less gular. The points of the lower denticulations are prolonged into threads, and end slightly to their attachments. At the lower end, the ligamentum denticu- tum may be regarded as continued into the terminal filament of the spinal rd, which thus connects it to the dura mater at the extremity of the sheath. he free edge, in the intervals between the denticulations, is slightly thickened, d in many parts is closely applied to the inner surface of the arachnoid, with hich it is often directly connected by fine trabeculæ. The denticulations do not

Fig. 321.

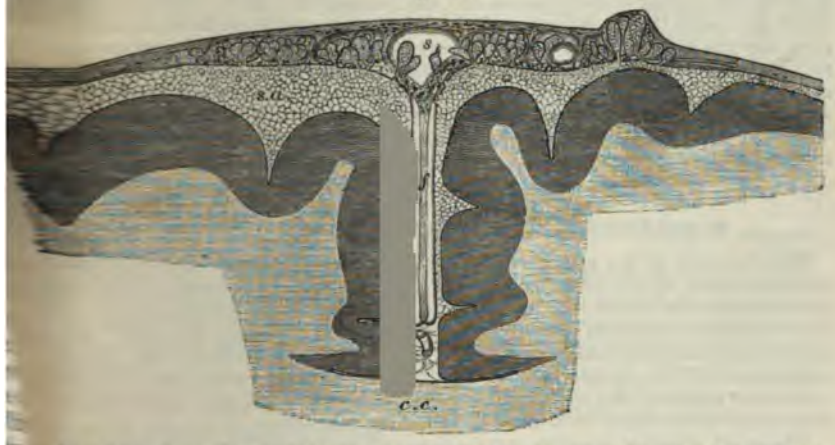


Fig. 321.—Section of the upper part of the brain and meninges to show the relations of the arachnoidal villi. (Key and Retzius). Magnified.

c. c, corpus callosum; *f*, falx cerebri; *s. a*, subarachnoid space, pervaded by a network of fine trabeculæ; from it the fungiform villi are seen projecting into the dura mater. Some are projecting into the superior longitudinal sinus, *s*.

perforate the arachnoid but receive from it funnel-shaped sheaths, which accompany them to the inner surface of the dura mater (Axel Key and Retzius).

In structure the ligament consists of white fibrous tissue, mixed with many exceedingly fine elastic fibres. Several layers of fine connective tissue trabeculæ may be traced: they are surrounded by sheaths, which are composed of delicate nucleated cells, and here and there expand into membranes. Its tissue is continuous on the one hand with that of the pia mater, and at the apices of the denticulations with that of the dura mater.

Glandulæ Pacchionii or arachnoidal villi.—Upon the external surface of the dura mater, in the vicinity of the longitudinal sinus, are seen numerous small pulpy looking elevations, generally collected into clusters, named glands of Pacchioni (fig. 321). The inner surface of the calvarium is marked by little pits, which receive these prominences. Similar excrescences are seen on the internal surface of the dura mater, and upon the pia mater on each side of the longitudinal sinus, and also projecting into the interior of that sinus (*s*). Occasionally they are found also in other situations.

...INAL CORD.

...these bodies it will be found ... dura mater and within the ... positions. But that they ... and in their growth ... a thickness were long the subject ... shown by Luschka that ... the arachnoid. On each ... venous spaces in the dura ... These communicate ... those which ... their inner part ... communicate with the ... derived from the dura ... with the subdural space ... communicate with the subarachnoid ...

... pass inward into the Pacchionian ... and thus to get into ... communication ... the subdural space ... it can be driven ... which are found in each ... lateralis sinus, into which the ... means of passage of ... the venous sinuses, ... from any cause in ...

... AND SPINAL CORD.

... the spinal cord are (1) the ... arteriorals, but single ... vessels derived from ... the paired pe... around the line of ... these vessels ramify in the ... and their ramifications ... arrangement.

... two systems, a cen... arterioles, 220 to ... into the anterior ... each one divides into ... arteries and capillaries ... grey matter: but an ... other side for anasto...

... arrangement, ... capillary loops, which ... distributed to the white ... intramedullary plexuses. But ... to the grey matter, and ... which permeates it, supplying the ... special mention may be made of a ... over the posterior fissure, pene... branches which supply the ... like a column, where this is ... the grey matter with the bundles of the ... distributed to the corresponding

... of the arteries. Two longitudinal venous vessels, one on ... of the central canal, accompanying the corresponding anastomotic

…ries, are conspicuous in most transverse sections of the cord. (For further …ils see Adamkiewicz in Trans. Internat. Med. Congress, London, 1881, and …Wiener Sitzungsberichte, 1881 and 1882.)

Blood supply of the brain.—The origin and course of the vessels which …ply the brain have already been described in the Section Angeiology, Vol. I. …passing to their distribution the several arteries, having passed across the …chnoid cavity, enter the subarachnoid space and then divide and subdivide into …nches, which, in their further ramification in the nervous centres, are sup…rted by the pia mater, and, it may be remarked, are more deeply placed in the …rious fissures and sulci than the small veins, which do not accompany the arteries, …t pursue a different course and are chiefly seen upon the surface of the pia mater. …om the arteries in the pia mater of the hemispheres very numerous small …anches pass vertically into the grey matter of the convolutions. Most of these …ertical arteries) at once break up into a close plexus of capillaries for the grey …atter; but others (*medullary arteries*), larger but less numerous, pass through …he grey matter, giving off only a few small branches to it, and penetrate for …ome distance into the medullary centre, where they divide into a long meshed …apillary network. The smaller branches of arteries anastomose together to a …ertain extent in the pia mater before penetrating into the superficial grey …matter, but the branches which pass to the chief ganglia, such as the optic tha…lamus or corpus striatum, do not anastomose with one another except by their …capillary branches (End-arterien of Cohnheim).

Moreover, it is to be observed that, whilst the main branches of the arteries are …situated at the base of the brain, the principal veins tend towards the upper surface …of the hemispheres, where they enter the superior longitudinal sinus: the veins …of Galen, however, coming from the lateral ventricles and choroid plexuses, …run backwards to the straight sinus, in the subarachnoid tissue which lies …between the two layers of the velum interpositum.

It may be convenient here to recapitulate the sources of the blood supply to …the several parts of the encephalon.

The **medulla oblongata and pons Varolii** are supplied by branches from …the anterior spinal, the vertebral, the basilar, and the posterior cerebral arteries. …The branches enter the pons and medulla in two sets, lateral or radicular (fol…lowing the roots of the nerves), and median,—the latter passing in the septum …to the grey matter on the posterior surface. The valve of Vieussens and the …superior peduncle of the cerebellum receive twigs from the superior cerebellar …arteries. The choroid plexuses of the fourth ventricle are supplied by the …posterior inferior cerebellar arteries.

Cerebellum.—The *under surface* is supplied by the posterior inferior cerebellar arteries from the vertebral, and the anterior inferior from the basilar. The *upper surface* is supplied chiefly by the superior cerebellar arteries from the basilar: its posterior portion from the posterior inferior cerebellar.

The **crura cerebri** derive their blood supply from the posterior communicating and the posterior cerebral arteries. Branches of the latter, and also others from the end of the basilar, enter the posterior perforated space.

The **corpora quadrigemina** and **corpora geniculata** are both supplied by the posterior cerebral artery, but branches of the superior cerebellar arteries pass to the inferior corpora quadrigemina.

The **optic thalamus** is supplied above and on the outer and posterior side by branches of the posterior cerebral artery, but its anterior and inner portions receive twigs from the anterior and posterior communicating arteries of the circle of Willis.

Cerebral hemispheres.—*Frontal lobe.*—The superior frontal and anterior two-thirds of the middle frontal convolution, with the upper extremity of the ascending frontal, are supplied by the anterior cerebral. The inferior frontal convolution, the posterior extremity of the middle frontal, and the greater part of the ascending frontal convolutions are supplied by the middle cerebral. The orbital surface is supplied, outside the orbital sulcus, by the middle cerebral: within that sulcus (including the olfactory bulb) by the anterior cerebral.

Parietal lobe.—All the convolutions of the parietal lobe are supplied by the middle cerebral artery.

Occipital lobe.—This lobe is supplied by the posterior cerebral artery.

Temporo-sphenoidal lobe.—The superior, and upper part of the middle temporo-sphenoidal convolutions are supplied by the middle cerebral artery. The lower portion of the lobe by the posterior cerebral.

Inner surface of the hemispheres.—The whole anterior and upper portion, as far back as the parieto-occipital fissure, is supplied by the anterior cerebral artery; the cuneate lobule and the occipito-temporal region by the posterior cerebral.

The *corpus callosum* is chiefly supplied by the anterior cerebral.

The *grey substance at the base* of the cerebrum is supplied by small twigs from the adjacent vessels of the circle of Willis, or from the roots of the cerebral vessels which pass off from that anastomosis.

Central parts—corpus striatum.—Both nucleus caudatus and nucleus lenticularis are supplied almost exclusively by the middle cerebral artery, the numerous branches to these parts entering through the foramina in the anterior perforated space. The anterior part of the caudate nucleus is also supplied by the anterior cerebral, and its upper surface receives fine twigs from the lateral choroidal branch of the posterior cerebral.

For further details on the subject, which derives importance from the relation of different local pathological conditions to the vascular distribution, the reader is referred to a series of articles by Duret in the Archives de Physiologie for 1873 and 1874, to a paper by Heubner in the Med. Centralblatt, 1872; and to a work entitled "Die luetische Erkrankung der Hirnarterien," Leipzig, 1874, by the same author.

Lymphatics.—The lymphatics of the brain and spinal cord appear to originate in the form of perivascular clefts in the adventitia, or outer coat of the blood-vessels. The clefts in question communicate both with lymphatic spaces in the pia mater, and with the subarachnoid space. The fine meshes of the neuroglial reticulum which are much more distinct in some parts than in others, the perivascular spaces which are thought to be in communication with those meshes, and a cleft-like space, which can be injected, between the pia mater and the surface of the spinal cord and brain (*subpial space*, *epicerebral space*), have also been regarded as forming part of the lymphatic system of the central nervous organs.

SIZE AND WEIGHT OF THE ENCEPHALON.

The average weight of the brain is about 49½ oz. (1400 grammes) in the male, and 5 to 5½ oz. less in the female.

The results obtained by Sims, Clendinning, Tiedemann, and J. Reid show the maximum weight of the adult male brain, in a series of 278 cases, to be 65 oz., and the minimum weight 34 oz. In a series of 191 cases, the maximum weight of the adult female brain was 56 oz., and the minimum 31 oz.; the difference between the extreme weights in the male subject being no less than 31 oz., and in the female 25 oz. In a very large proportion the weight of the male brain ranges between 46 oz. and 53 oz., and that of the female brain between 41 oz. and 47 oz. The *prevailing* weights of the adult male and female brain may therefore be said to range between those terms; and, by taking the mean, an *average* weight is deduced of 49½ oz. for the male, and of 44 oz. for the female brain,—results which correspond closely with the statements generally received.*

Although many female brains exceed in weight particular male brains, as a general fact it may be affirmed that the adult male encephalon is heavier than

* Tables exhibiting at greater length the results obtained by the observers above mentioned, and also those obtained by R. Boyd of the weight of the brain at different ages, will be found in previous editions of this work. The reader is also referred to the papers by Peacock in the Edin. Med. Journal for 1847, and Journ. of the Pathol. Society, 1860, to the elaborate table of Rud. Wagner in his "Vorstudien, &c.," 1860, and to a recent work by Bischoff (Hirngewicht des Menschen, Bonn, 1880).

of the female. In new-born infants the brain was found by Boyd to weigh
n average 11.65 oz. in the male, and 10 oz. in the female.
e observations of Sims, Tiedemann, and Reid, appear to show that in both
s the weight of the brain in general increases rapidly up to the seventh year,
more slowly to between sixteen and twenty, and again more slowly to
een thirty-one and forty, at which time it reaches its maximum point.
nd that period there appears a slow but progressive diminution in weight,
unting to about 1 oz., during each subsequent decennial period; thus con-
ing the opinion that the brain diminishes in advanced life. According to
ock and Bischoff, the maximum weight of the brain is attained between
ages of twenty and thirty years.
nce exercises a considerable influence upon the size of the brain; thus it is
est in Europeans and Chinese; smaller in Hindoos, Bushmen and Negritoes
tly in relation to the small prevailing stature) and natives of Australia;
rmediate in size between these in North American Indians and Negroes.
he *relative weight of the encephalon to the body* is liable to great variation;
ertheless, the facts to be gathered from the observations of Clendinning,
demann, and Reid, furnish the following general result. In a series of 81
es, the average proportion between the weight of brain and that of the body
he ages of twenty years and upwards, was found to be as 1 to 36·5; and in a
es of 82 females, to be as 1 to 36·46. The results of Bischoff's observations
e 1 to 35.2 in the female. In these cases the deaths were the result of more
ess prolonged disease; but in healthy individuals dying suddenly from
ase or accident, the average proportion is probably 1 to 45.
he proportionate weight of the brain to that of the body is much greater at
h than at any other period of life, being, according to Tiedemann, about 1
·85 in the male, and about 1 to 6·5 in the female. From the observations
ady referred to, it further appears that the proportion diminishes gradually
to the tenth year, being then about 1 to 14. From the tenth to the twentieth
r, the relative increase of the body is most striking, the ratio of the two
ng at the end of that period about 1 to 30. After the twentieth year, the
eral average of 1 to 36·5 prevails, with a further trifling decrease in advanced
.*

he attempts hitherto made to measure or estimate the relative proportions of
different convoluted parts of the cerebrum to each other and to the degree of
lligence, either more directly or by the craniospic methods, have been
nded with little success. Such researches as those of Rudolph Wagner give,
ever, some promise, when fully carried out, of affording more definite
lts. These researches had for their object to institute an accurate comparison
reen the brains of certain persons of known intelligence, cultivation, and
tal power, and those of persons of an ordinary or lower grade. As examples
rains of men of superior intellect he selected those of Professor Gauss, a
-known mathematician of eminence, and Professor Fuchs, a clinical teacher;
as examples of brains of ordinary persons, those of a woman of 29 and a
man.
he careful measurement of all the convolutions and the intervening grooves
he four brains above mentioned has been carried out by H. Wagner, and the
lt of these measurements is partly given in the accompanying table (see
page), the numbers indicating square inches of surface.
will be seen that although there are undoubtedly differences in the brains
mined, these are by no means so striking as might have been expected.
ed it may be stated that the general result of these and similar observations
been hitherto inconclusive, for although there have been observed several
ble instances in which superiority of intellect has been found to be accom-
ed by increased size or complexity of the cerebral surface, in many other
s no such relation has been noticed.

* On the relation between the weight of the brain and the individual stature, see
Marshall, Proc. Roy. Soc. 1875: le Bon, Rev. d'Anthrop., 1879, and Bischoff, in the
above-mentioned.

Comparative measurement of the extent of surface of the Convolutions of Cerebrum and its lobes.

	Surface of each lobe separately.				Free and deep surfaces of Cerebrum.		W
	Frontal.	Parietal.	Occipital.	Temporal.	Free surface.	Deep or covered surface.	Co
1. Gauss	139.	70.6	59.4	68.4	112.8	228.2	
2. Fuchs	143.4	69.5	59.	67.5	110.7	231.3	
3. Woman	130.	65.	51.	66.8	107.5	209.9	
4. Workman ..	113.2	62.3	50.5	62.	97.4	193.6	

WEIGHT OF THE SEVERAL PARTS OF THE ENCEPHALON

As the result of observations made in reference to this subject, on th of 53 males and 34 females, between the ages of twenty-five and fifty-fi Reid has given the following tables:—

	Males. oz.	drs.	Females. oz.	drs.
Average weight of cerebrum	43	15¾	38	12
„ cerebellum	5	4	4	12¼
„ pons and medulla oblongata .	0	15¾	1	0¼
„ entire encephalon . .	50	3½	44	8½

With these results the observations of Huschke, and of Weisbech, main

From this it appears that the proportionate weight of the cerebellum of the cerebrum is, in the male, as 1 to 8¼, and in the female, as 1 to 8½.

In the new-born infant the ratio of the weight of the cerebellum to th whole brain is strikingly different from that observed in the adult. found the weight of the cerebellum, medulla oblongata, and pons togeth new-born infant, as compared with that of the brain, to be in the prop 1 to 15, and 1 to 13. In the adult the proportions were 1 to 7, and 1 to

Meynert found the proportions between the frontal, parietal, and o occipital and temporo-sphenoidal lobes to be 41·5 : 23·4 : and 35·1.

WEIGHT OF THE SPINAL CORD.

Divested of its membranes and nerves, the spinal cord in the huma weighs from 1 oz. to 1¾ oz. Its proportion to the encephalon is about 1

SPECIFIC GRAVITY OF THE ENCEPHALON.

The specific gravity of the different parts of encephalon has of late some attention from the fact having been observed that it varies to some different kinds of disease. From the researches of various observers, that the average specific gravity of the whole encephalon is about 103 the grey matter 1034, and that of the white 1040. There are also co differences in the specific gravity of some of the internal parts. Comp specific gravity of the white and grey substances respectively with th whole brain, Danilewsky has calculated that about 33 per cent. of the the hemispheres is due to the grey cortex, or including the basal gan 35·5 per cent.*

* For the recent literature of the brain and spinal cord the reader is refer important work by Schwalbe (Lehrbuch der Neurologie, Erlangen, 1881), where with great completeness, and where many more details regarding the struct central nervous system may be found than could conveniently be introduced similar work by Henle (Nervenlehre, Brunswick, 1879) may also be consulted with

ORGANS OF THE SENSES.

s place will be described the organs of sight, hearing, and smell gher organs of special sense. The description of the organ of given with the skin, and that of the organ of taste with the

THE EYE.

rgan of vision, strictly speaking, consists only of the ball or the eye ; but connected with the eyeball externally are muscles, nd blood-vessels, elsewhere described, as well as other parts destined for its protection, and known as the appendages of the mina oculi), of which an account will first be given.

THE EYELIDS AND CONJUNCTIVA.

elids (*palpebræ*) are moveable portions of integument, strengthards their margins by a thin lamina of dense fibrous tissue (*lar*- mucous membrane (*conjunctiva*) lines their inner surface, and d thence on the front of the eyeball. The line of reflection is ne *fornix* of the conjunctiva.

Fig. 322.

-FRONT VIEW OF THE RIGHT TH THE EYELIDS DRAWN APART T HOOKS (Merkel).

semilunaris ; *Pls*, *Pli*, punc- male sup. et inf. ; *Car*, carun- ymalis ; *Lpm*, internal tarsal

pper lid is larger and oveable than the lower, transparent part of the ing covered by it when s closed; it is chiefly by tion of this lid that the ned, the movement being by a muscle (*levator pal*- evoted exclusively to this At the outer and inner *anthi*) of the eye the e united. The interval between the angles varies in different ds, and, according to its extent, gives the appearance of a a smaller eye, the size of the globe being nearly the same in greater part of the edge of each eyelid is flattened and angular, rds the inner canthus it is rounded off for a short space, at the e that it changes its direction ; at this point there is seen on a slight elevation (*papilla lachrymalis*,)—the apex of which is by the aperture (*punctum*) of a small canal (*canaliculus lachry*- hich serves to convey away the fluid which moistens the con- (fig. 322, *Pli*).

greater part of their extent the lids are applied to the surface eball ; but at the inner canthus, opposite the apertures, there s a vertical fold of conjunctiva, the *plica semilunaris* (fig. 322,

Ps), which rests on the eyeball ; whilst, occupying the recess of t
the border of this fold, is a spongy-looking reddish elevation
lachrymalis, Car) formed by a small insulated portion of skin c
few large modified sweat glands, as well as a group of sebac
which open into the follicles of very fine hairs. There is fu
in it a small amount of plain muscular tissue (H. Müller),

Fig. 323.

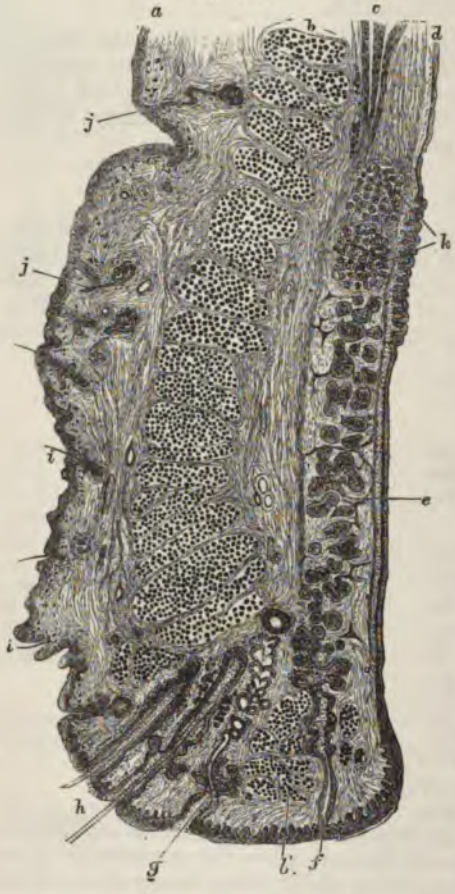


Fig. 323.—VERTI
THROUGH THE U
HUMAN (after Wa
NIFIED.

a, skin ; *b*, or
ciliary bundle ; c
muscle of eyelid ; d
e, tarsus ; *f*, Meil
g, sebaceous gland
with modified sweat
with it ; *h*, eyelas
hairs in outer sk
glands ; *k*, pos
glands.

few cross-striate
fibres. A few p
lar fibres are
found in the pl
naris.

The plica semil
rudiment of the
(membrana nictita
many animals ; a
animals, and occ
man, the carunc
malis retains its
with the skin at
canthus.

Structure of
—The skin cov
eyelids is thin an
and covered with
hairs (fig. 323, *i*,
line of the eyelas
the conjunctiva
membrane which
inner surface of
The cutis vera
number of ramified pigment cells. Beneath the skin is a quant
connective tissue free from fat and containing the fasciculi of
laris oculi muscle (*b*), and beneath the mucous membrane on th
surface is the lamina of dense connective tissue before mention
known as the tarsus, or from its consistence, the tarsal cartil
thins off near the attached margin of the eyelid into the palpebr
connecting it with the margin of the orbit. In the tarsi ar
the Meibomian glands (*f*). In the upper eyelid there is, i
the insertion of the levator palpebræ superioris, in the

expansion attached to the upper or anterior surface of the

orbicularis muscle is closely attached to the skin by connective but glides loosely on the tarsal cartilages. A marginal fasciculus thin the line of the eyelashes, separated by the bulbs of the lashes the other fibres, and constituting the *ciliary bundle* (*b'*). The of the orbicularis are very small. Its attachments have already been bed in vol. I.

tarsi (*tarsal cartilages*) are two thin elongated plates formed of connective tissue, without, according to most observers, any inter- re of cartilage-cells. They are placed one in each lid, to which ive shape and firmness. The upper one, the larger, is half oval m, being broader near the centre and narrowing towards the of the lids. The lower is thinner, much narrower, and more of an uniform breadth throughout. Their free edge, which is t, is thicker than any other part. At the inner canthus they are o the nasal process of the superior maxillary bone by the internal slip (vol. I., p. 273); and at the outer angle are attached to the bone by a fibrous band termed the outer tarsal ligament.

palpebral ligament is a fibrous membrane placed beneath the laris muscle, attached on the one hand to the margin of the orbit, the other to the tarsi, with which its tissue is continuous. The ane is thickest at the outer part of the orbit.

the ocular surface of each lid are seen from twenty to thirty l vertical rows of what look like yellow granules, lying immediately the conjunctival mucous membrane; these are the *Meibomian* (fig. 324, 6, 6). They are long sebaceous glands, imbedded in the and they open on the free margin of the lids by minute orifices, ally one for each. The glands consist of nearly straight tubes, at the end, with numerous small cæcal appendages projecting the sides. The mouths of the tubes are lined by stratified epithelium uous with that of the skin: but the ducts and the glandular recesses a lining of cubical epithelium filled with the fatty secretion. rding to Colosanti the glands have a basement membrane, and a

Fig. 324.

24.—MEIBOMIAN GLANDS OF LEFT EYELIDS AS SEEN FROM IND.

a, palpebral conjunctiva; 1, mal gland; 2, openings of seven t of its ducts; 3, upper and puncta lachrymalia; 6, 6, ends upper and lower Meibomian , of which the openings are ed along the margins of the .

lar layer outside this: ther describes a network e nervous fibrils amongst ithelium-cells.

yer of unstriped muscular tissue is contained in each eyelid; that of the (fig. 323, *e*) arising from the under surface of the levator palpebræ, that of ver from the neighbourhood of the inferior oblique muscle, and each being d near the attached margin of the tarsus. It may also be mentioned in

and longer than the lower, and are curved in an opposite dire

Near the inner canthus the hairs are weaker and more scattered. within the eye-lashes, between them and the ciliary bundle of the a row of large modified sweat-glands, which open into the mou sebaceous glands (fig. 323, *g*) (not the Meibomian).

The *conjuntiva* consists of the palpebral part (conjunctiva with which may be included the plica semilunaris and carunc the ocular part (conjunctiva bulbi), in which may be disting sclerotic and corneal portions: each of these parts presents characters. The epithelium of the conjunctiva varies so different parts, but is mainly columnar, with smaller cells b fixed ends of the columnar cells. Near the skin and cornea i into the stratified epithelium which covers these parts.

The *palpebral portion* of the conjunctiva is thicker and mo than the rest of the membrane, and is freely supplied wi Through the puncta lachrymalia and canaliculi, it is conti the lining membrane of the lachrymal sac. Although clos to the tarsi, it exhibits, nevertheless, numerous small creas which are visible with a lens. A layer of small racemose racemose glands is found on the ocular surface of the lids, ir under the conjunctiva, and beyond the blind ends of the glands (fig. 323, *k*). Their minute ducts open near the line o of the conjunctiva upon the globe of the eye.

The *ocular portion*.—The conjunctiva changes its charac line of reflection from the eyelids, becoming thinner and bei connected to the sclerotic coat of the eyeball by submucous tis over the cornea it consists only of a prolongation of the e which is closely adherent to the anterior layers of the cornea, tion with which it will be described.

Vessels and nerves.—Only a few of the larger blood-vessels a visible in the conjunctiva in the healthy condition, but in the inflammatory congestion a copious network of vessels very irregula comes into view. These are derived from the *palpebral* and *lachry*

ell developed network of *lymphatics* exists throughout the sclerotic and eral portions of the conjunctiva; but at the margin of the cornea a sudden ition takes place in the size of the meshes and diameter of the vessels, become irregular and pointed, and come into connection with ramified aces in the cornea.

ay of the *nerves* in the conjunctiva, as far as the cornea, terminate, as was by Krause, in end-bulbs. These have already been sufficiently described 0.)

mucous membrane of the conjunctiva contains a large quantity of lymphoid especially at its back part. Lymphoid nodules are also occasionally present, ldom in man.

THE LACHRYMAL APPARATUS.

he parts which constitute the lachrymal apparatus are the following, :—The gland by which the tears are secreted; the two canals which t the fluid near the inner canthus, and the sac with the nasal duct nued from it, through which the tears pass into the inferior meatus e nose.

e **lachrymal gland** (fig. 324, 1), an oblong flattened body, about ize of a small almond, is placed in the upper and outer part of the

Fig. 325.

25.—FRONT OF THE LEFT EYELIDS H THE LACHRYMAL CANALS AND AL DUCT EXPOSED.

, upper and lower lachrymal canals, ag towards the eyelids the narrow ortions and the puncta lachrymalia; hrymal sac; 3, the lower part of asal duct; 4, plica semilunaris; 5, ula lachrymalis.

, a little behind the anterior in. The upper convex sur- of the gland is lodged in a t depression in the orbital of the frontal bone, to the steum of which it is united ibrous bands; the lower sur- is adapted to the convexity he eye-ball, and is in contact the upper and the outer recti muscles. The fore part of the d, separated from the rest by a thin layer of fascia, and some- s described as a distinct gland (*glandula lachrymalis inferior* of nmüller), is closely adherent to the back of the upper eye-lid, and is red on the ocular surface merely by the conjunctiva; its lobules are l and separate, with minute ducts, some opening separately, others ng the ducts from the principal gland, which are also very small. number from both divisions of the gland seldom exceeds twelve or een. After running obliquely under the mucous membrane, and ating at the same from each other, they open in a row at the fornix nctivæ, by separate orifices, at its upper outer part.

lachrymal gland is a compound racemose gland resembling the salivary in general structure. Its alveoli are bounded by a basement membrane d of ramified flattened cells; and the secreting cells exhibit changes in the nt states of rest and activity of the gland similar to those seen in most

other glands (see p. 223). No rod-like structure has been noticed in t
of the ducts.

Lachrymal canals.—These commence as already men
minute aperture (*punctum*) on the margin of each lid, ne
angle (fig. 325, 1, 1). The upper canal is rather the
longer of the two: it first ascends from the punctum; th
sudden bend, and is directed inwards and downwards to jo
rymal sac (fig. 325, 2). The lower canal descends from the c
punctum and then takes a nearly horizontal course inwards.
are dilated where bent. In some cases they unite near the end
monly they open separately, but close together, into the sac.

The **lachrymal sac** and **nasal duct** constitute together
by which the tears are conveyed from the lachrymal canals t
of the nose. The lachrymal sac (fig. 325, 2), the slightly d
portion of the passage, is situated at the side of the nose, ne
canthus of the eye, and lies embedded in a deep groove in
and superior maxillary bones. Its upper end is closed and r
the lower end gradually narrows into the nasal duct. On th
and a little in front, it receives the lachrymal canals; an
placed behind the tendo palpebrarum, and some of the inner
orbicular muscle of the lids; while on its orbital surface i
tarsi muscle. The nasal duct, about half an inch or rath
length, grooving the upper maxilla, descends to the fore
lower meatus of the nose, the osseous canal being compl
ungual and lower turbinate bones. Both sac and duct a
of fibrous and elastic tissues, adhering closely to the b
mentioned, and strengthened in the case of the lachrymal sac
process sent from the tendo palpebrarum, which crosses it a
its middle. The inner surface is lined by a mucous memb
is continuous through the canaliculi with the conjunctiva, a
the nasal duct with the mucous membrane of the nose.

At the opening into the nose it is often arranged so as
imperfect valve (Hasner). The nasal duct is rather narr
middle than at either end; its direction is not quite vertical, b
slightly outwards and backwards.

The mucous membrane in the canaliculi possesses a str
epithelium, but in the nasal sac and duct a ciliated epitheliu
nose.

THE GLOBE OF THE EYE.

The globe or ball of the eye is supported by a quantity of
connective tissue in the centre of the fore part of the or
The recti and obliqui muscles closely surround the greater
eyeball, and are capable of changing its position within cer
the lids, with the plica semilunaris and caruncle, are in cont
covering of conjunctiva in front; and behind it receives the
of the optic nerve.

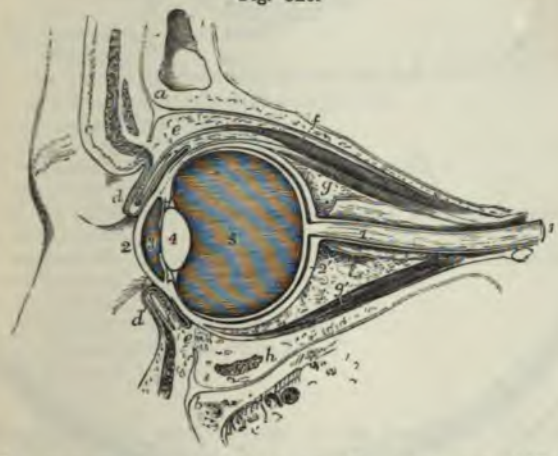
The eyeball is composed of segments of two spheres, o
anterior is the smaller and more prominent; the segment c
posterior opaque sphere corresponds with the limit of the s
and that of the smaller sphere with the cornea.

The eyeball measures about an inch across from side to si
above downwards, but not quite a full inch from before back

t when directed towards near objects, the axes of the eyes are arallel ; the optic nerves, on the contrary, diverge considerably. rve enters the corresponding eye about a tenth of an inch to r or nasal side of the axis of the eyeball.

yeball consists of three concentric coats, and of certain fluid and rts enclosed by them. The coats are (1) an external fibrous , forming the *sclerotic* and *cornea*, (2) a middle vascular, pig- and in part also muscular membrane, the *choroid* and *iris*, and (3) nal nervous and epithelial stratum, the *retina*. The enclosed

Fig. 326.



—VERTICAL SECTION OF THE LEFT ORBIT AND ITS CONTENTS. (Allen Thomson.)

ion has been carried first obliquely through the middle of the optic foramen nerve as far as the back of the eyeball, and thence forward through the eyeball, . *a*, frontal bone ; *b*, superior maxillary ; *c*, eyebrow ; *d*, the upper, and *d'*, eyelid, partially open, showing the section of the tarsi, the eyelashes, &c. ; *e*, *e*, ion of the conjunctiva from the upper and lower eyelids to the surface of the , the levator palpebræ superioris muscle ; *g*, the upper, *g'*, the lower rectus , the inferior oblique muscle divided ; 1, 1, the optic nerve divided in its , the cornea ; 2', the sclerotic ; 3, aqueous chamber ; 4, crystalline lens ; 5, amber

g media, three in number, are the *aqueous humour*, the *vitreous* d the *lens*.

d the middle of the eyeball there is an adventitious tunic of *nica vaginalis oculi*, or *capsule of Tenon*, which is perforated by ons of the recti and obliqui muscles, and connected with the by merely the most delicate connective tissue (except posteriorly, entrance of the ciliary vessels and nerves, where it blends sclerotic). This capsule is lined by flattened epithelial cells, ses a lymph-space, which separates the eyeball from the orbital enables it to glide freely in its movements.

THE SCLEROTIC COAT.

clerotic coat, the tunic of the eye on which the main- f the form of the organ chiefly depends, is a strong, opaque,

Fig. 327

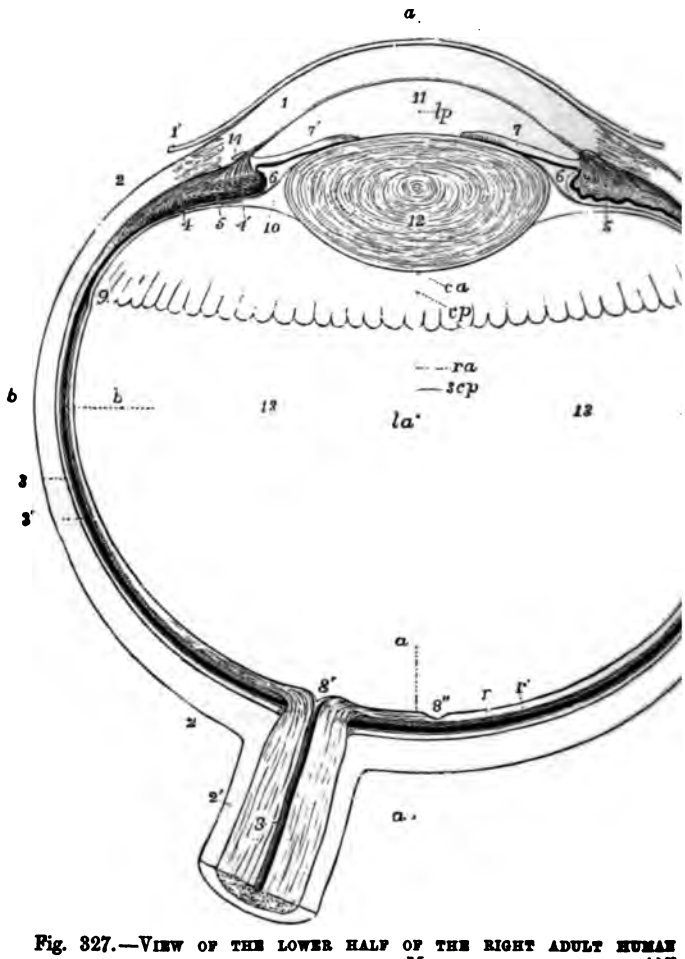


Fig. 327.—VIEW OF THE LOWER HALF OF THE RIGHT ADULT HUMAN HORIZONTALLY THROUGH THE MIDDLE. MAGNIFIED FOUR TIMES. (Alle

The specimen from which this outline is taken was obtained by dividing man of about forty years of age in the frozen state. It was carefully compa specimens obtained in a similar manner; and in the drawing averages ha in any particulars in which differences among them presented themselves.

1, cornea; 1', conjunctiva; 2, sclerotic; 2', dural sheath of the optic into the sclerotic; 3, 3', choroid; 4, 4', ciliary muscle; 5, ciliary process the posterior division of the aqueous chamber, in front of the suspenso the lens; 7, 7', the iris; 8, central artery of the retina; 8', colliculus of th 8'', fovea centralis; 9, ora serrata; 10, so-called canal of Petit; 11, aqu 12, lens; 13, vitreous humour; *a*, *a*, *a*, axis of the eye; *b*, *b*, *b*, *b*, equ be observed that from the pupil being placed nearer the inner side the a ball, *a*, *a*, does not pass exactly through the centre of the pupil; this li little to the inner side of the fovea centralis. The following letters indic of the curvatures of the different surfaces, assuming them to be nearly spher of the anterior surface of the cornea; *c p*, posterior surface; *l a*, anterior lens; *l p*, posterior surface; *s c p*, posterior surface of the sclerotic; *r a*, a the retina.

ion with this figure the following average dimensions of the parts
eye in fractions of an English inch may be stated :—

diameter of the eyeball	1·
ameter (Krause)	0·96
terior diameter	0·96
ickness of the sclerotic, choroid, and retina together	0·08
ickness of the sclerotic posteriorly	0·05
ickness at the sides and in front	0·025
of the cornea in the centre	0·04
om the middle of the posterior surface of the cornea to the the lens	0·1
terior diameter of the lens	0·16
ditto	0·36
ickness of the ciliary muscle	0·04
of the iris	0·015
the radius of curvature of the anterior surface of the regarding it approximately as spherical)	0·305
the posterior surface	0·275
the posterior surface of the sclerotic	0·5
curvature of the anterior surface of the lens	0·328
the posterior surface	0·24
f the middle of the posterior surface of the lens from the of the retina	0·575
etween the centre of the spot of entrance of the optic nd the middle of the fovea centralis retinæ	0·14
f the base of the cornea	0·48
f the base of the iris transversely	0·45
f the base of the iris vertically	0·43
f the pupil	0·14

ucture. It extends over about five-sixths of the eye-ball ,) joining in front with the cornea. The outer surface is smooth, except where the tendons of the recti and obliqui e inserted into it. The inner surface is of a light brown rough from the presence of a delicate pigmented connective *ibrana fusca*), which is united by fine threads with the choroid e filaments traverse a lymphatic space through which branches ary vessels and nerves also pass obliquely. The sclerotic is the back part of the eye, and thinnest at about a quarter of an he cornea: at the junction with the latter, it is again somewhat

The optic nerve pierces this coat about one-eighth or one- n inch internal to the axis of the ball, and the opening is smaller at the inner than at the outer surface of the coat. fibrous sheath of the nerve blends with the sclerotic at the the aperture : in consequence of this arrangement, when the nt off close to the eye-ball, the funiculi seem to enter by a pores ; and to the part of the sclerotic thus perforated the *amina cribrosa* is sometimes given. Around this cribrous e smaller apertures for vessels and nerves.

ure of the sclerotic.—The sclerotic coat is formed of bundles ive tissue fibres, and yields gelatine on boiling. Its white combined with fine elastic elements, and amongst them lie connective tissue corpuscles lodged in cell-spaces, but not by so regularly arranged as in the cornea. Some of the cells are . The bundles are disposed in layers both longitudinally and y, the longitudinal arrangement being most marked at the sur-

faces. These layers communicate at intervals so as not to be for any distance.

Both externally and internally the sclerotic is covered with flattened cells, which are reflected over the muscles, vessels, nerves, and connective of tissue which pass from it to the capsule of Tenon and the choroid respectively. The lamina fusca resembles in structure the lamina supra of the choroid coat.

At the back of the eye-ball, opposite the fovea centralis of the sclerotic is traversed in its thickness by a strand of fibrous tissue, which the laminæ as it passes through them. This fibrous strand is known as *funiculus sclerœ* (Hannover).

A few blood-vessels permeate the fibrous texture in the form of a capillaries with very wide meshes. In the neighbourhood of the cornea of greater vascularity exists, which has been already noticed in the description the sclerotic conjunctiva.

THE CORNEA.

The **cornea**, the transparent fore part of the external coat light into the interior of the eyeball. It is nearly circular but is occasionally wider in the transverse direction, and extends to about one-sixth of the circumference of the whole. Having a curvature of a smaller radius than the sclerotic jects forwards beyond the general surface of curvature of brane : the degree of its curve varies, however, in different persons at different periods of life in the same person, being more prominent youth than in advanced age. Its thickness is in general same throughout, viz., from $\frac{1}{12}$ to $\frac{1}{32}$ of an inch, excepting to periphery where it becomes somewhat thicker. The posterior surface exceeds slightly in extent the anterior or convex, in consequence of the latter being encroached on by the superficial part of the the cornea being overlapped by the sclerotic (to which however joined by continuity of tissue) like a watch glass by the edge groove into which it is received (see fig. 327).

STRUCTURE OF THE CORNEA.

The cornea may be described as consisting of three parts—an epithelium in front (fig. 329, 1) continuous with the epithelium conjunctiva ; a middle part, substantia propria, or cornea continuous with the sclerotic, composed of modified connective and a homogeneous elastic lamella (4), bounding it behind covered with a simple layer of epithelium-like cells (5).

Epithelium of the Cornea.—The epithelium covering the cornea is of the stratified kind (fig. 328). The lowermost are columnar, with a flattened base, where they rest on the propria, and a rounded apex, upon which a cell of the fits. To the base of each columnar cell is attached a broad strongly refracting process, which projects under one of the next cells (not shown in the figure). Above these columnar cells three layers of polygonal cells, some of the deeper of which (cells of Cleland) have projections from their under surface between the cells below. These polygonal cells present denticulations, which join one another across in the intercellular which separate the cells. Quite superficially is a stratum of scaly epithelium cells, which retain their nuclei.

ne proper substance of the cornea is composed, as before said, of dified form of connective tissue, all the constituents of which have nearly the same index of refraction, so that in the perfectly fresh ition it is difficult, even with the best lenses, to make out any ations of structure. After death, however, and with the assistance agents, the cornea may be ascertained to consist of alternating llæ of fibrous tissue (about sixty in number, Bowman), the planes of h are parallel to the surfaces of the cornea. The fibres composing amellæ are nearly straight and have a definite direction in each layer;

Fig. 328.

Fig. 328.—VERTICAL SECTION THROUGH THE EPITHELIUM OF THE CORNEA, HUMAN. (E. A. S.) Highly magnified.

deepest columnar cells; *p*, polygonal cells, immediately above them; *fl*, flattened of the surface.
he section is slightly broken on the right of the figure. The intercellular channels ged across by processes extending from one cell to another are distinctly seen.

y cross one another at right angles in the alternate layers (fig. 329, *b*, *d*). must, however, be understood that the latter are not individually tinct, but give off frequent offsets to the layers above and below, so t they cannot readily be stripped away for any distance. The fibrils collected into roundish bundles, which, as well as the laminæ they m, are, as in the connective tissue elsewhere, separated from each her by ground-substance. The latter is in greater abundance between e fibrous strata than elsewhere, and in these parts the cell-spaces of the ssue are found. These cell-spaces, which are readily demonstrated by staining the tissue with nitrate of silver (fig. 331), are flattened conformably with the lamellæ, are of an irregularly stellate figure, and freely communicate by their offsets both with others on the same plane and with those above and below. The greater regularity of arrangement which characterises them, as compared with the cell-spaces of connective tissue elsewhere, is dependent on the regularly laminated structure of the cornea.

The corpuscles of the tissue—*corneal corpuscles*—lie within the cell-spaces, corresponding generally with them in form, but without entirely filling them, the room left serving for the passage of lymph and lymph-corpuscles. The protoplasm of the corpuscles is clear, except in the neighbourhood of the nucleus, where it is more granular; the cells send branching processes along the anastomosing canals of the cell-spaces, which join with those of neighbouring corpuscles. In vertical sections the corpuscles appear fusiform (fig. 329, *c*), but horizontal sections show them to be flattened conformably with the surface (fig. 330).

In the human cornea the cell-spaces can be filled with fluid injec
inserting the nozzle of a fine syringe into the tissue, and employing a
pressure; in this way a network of anastomosing stellate figures is
(Recklinghausen's canals); if, however, the injection-fluid be too consi
if too great force be employed, the injection becomes extravasated in the
stices of the fibril-bundles, the direction of which it takes; and the ap

Fig. 329.

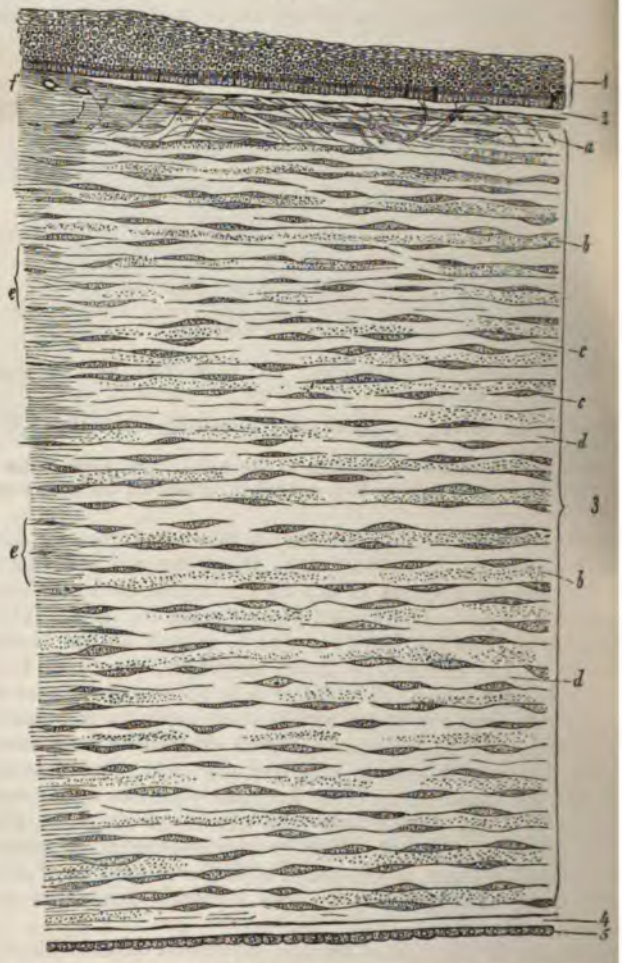


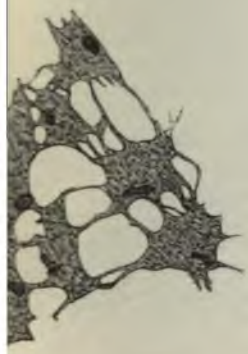
Fig. 329.—Vertical section of human cornea from near the margin (W
Magnified.

1, epithelium; 2, anterior homogeneous lamina; 3, substantia propria cornea
terior homogeneous (elastic) lamina; 5, epithelium of the anterior chamber;
fibres in the anterior layer of the substantia propria; *b*, lamellæ the fibres of
cut across, producing a dotted appearance; *c*, corneal corpuscles appearing fu
section; *d*, lamellæ the fibres of which are cut longitudinally; *e*, transition to the
with more distinct fibrillation, and surmounted by a thicker epithelium; *f*, sm
vessels cut across near the margin of the cornea.

ed of minute swollen tubular passages running at right angles to one n the different layers (Bowman's corneal tubes). This appearance may readily be obtained if air is injected into the tissue instead of mercury used by Bowman), and it is seen that the injection always stops at the f the cornea, where the tissue becomes denser as it passes into the whereas Recklinghausen's canals are continued into the cell-spaces of r.

part of the cornea immediately beneath the anterior epithelium, ickness of from $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch, is denser than the rest tissue, and entirely free from corpuscles (fig. 329, 2). It was he anterior elastic lamina by Bowman, but appears not to differ lly in structure from the rest of the corneal substance, fibres from nay be seen passing obliquely towards, and becoming lost in it 9, *a*).

Fig. 330.



30.—Corpuscles of the rat's ea. From a preparation treated chloride of gold. (E.A.S.)

Fig. 331.

Fig. 331.—Cell-spaces of the rat's cornea. From a preparation stained with nitrate of silver. (E.A.S.)

membrane of Descemet or Demours (fig. 329, 4) (posterior lamina, Bowman), not very closely united with the fibrous part of rnea, is transparent and glassy in appearance. It is firm and ureless, but very elastic ; and when shreds are removed from it end to curl up with the attached surface innermost. It appears be affected by acids, by boiling in water, or by maceration in s, but under some conditions it can be split up into very fine e. In thickness it varies from $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch. It is next the anterior chamber with an epithelium (fig. 329, 5), which les that on serous membranes, consisting of a single layer of ed polygonal cells with distinct nuclei.

ts circumference the membrane breaks up into bundles of fibres, are partly continued into the front of the iris, forming the "pillars iris" and partly into the fore part of the choroid and sclerotic To these festoon-like processes passing between the iris and pos- art of the cornea at its junction with the sclerotic, and which are uch more marked in the eyes of the sheep and the ox than in the

human eye, the name *ligamentum pectinatum iridis* was giv
Hueck. The processes in question are covered with epithelioid cel
tinued from Descemet's membrane, but these cells do not stretch
the *intervals* between the processes, so that the cavity of the a
chamber is prolonged into, and freely communicates with, ca
spaces (*spaces of Fontana*) in the tissue between the processes (fig.

Fig. 332.

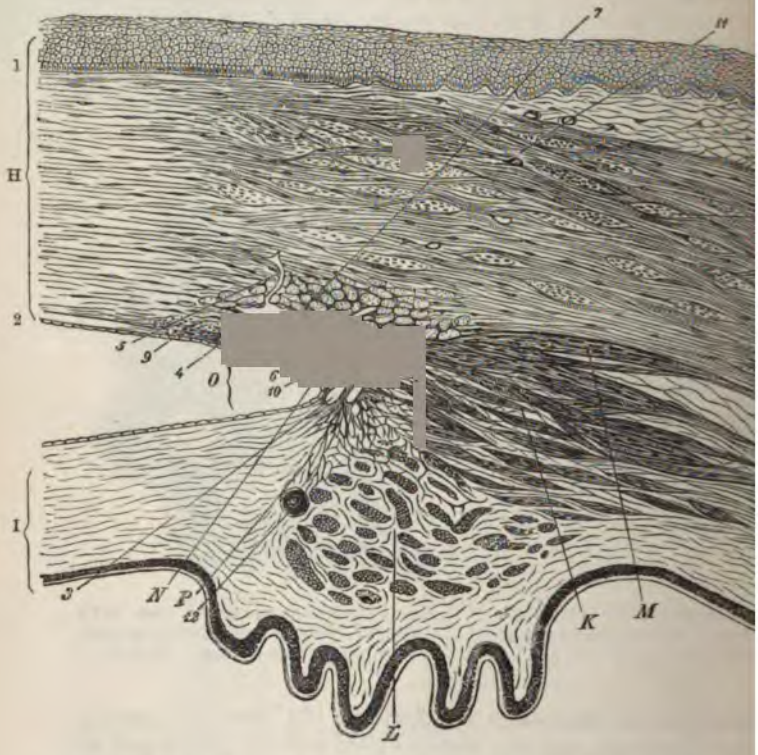


Fig. 332.—SECTION (FROM THE EYE OF A MAN, AGED 30), SHOWING THE
OF THE CORNEA, SCLEROTIC, AND IRIS, TOGETHER WITH THE CILIARY MU
THE CAVERNOUS SPACES NEAR THE ANGLE OF THE ANTERIOR CHAMBER (
MAGNIFIED.

A, epithelium; B, conjunctival mucous membrane; C, sclerotic; D, sup
space and laminæ; E, opposite the ciliary muscle; F, choroid, with ciliary
G, pars ciliaris retinæ; H, cornea; I, iris; K, radiating and meridional, and L,
annular bundles of the ciliary muscle; M, bundles passing to the sclerotic; N, li
pectinatum iridis at the angle, O, of the anterior chamber; P, line of attachm
iris; 1, anterior homogeneous lamina of the cornea; 2, posterior homogeneo
covered with epithelial cells which are continued over the front of the iris; 3,
spaces at the angle of the anterior chamber (spaces of Fontana); 4, canal of
with epithelial lining, and with a vessel, 5, leading from it; 6, other vessels;
of fibres of the sclerotic having a circular direction, cut across; 8, larger c
substance of the sclerotic; 9, fine bundles cut across, at limit of cornea; 1
origin of meridional bundles of ciliary muscle; 11, blood-vessels in sclerotic
junctiva, cut across; 12, section of one of the ciliary arteries.

lar, but rather larger space is found slightly anterior to these in the nce of the sclerotic, close to its junction with the cornea. This, is elliptical in section, is known as the *sinus circularis iridis*, or *of Schlemm* (fig. 332, 4).

rding to Schwalbe, the canal of Schlemm communicates, through the other with the aqueous chamber of the eye. But, on the other hand, the canal lemm, and the other cavernous spaces in its neighbourhood, are in com- ation with the *veins* of the anterior part of the sclerotic, and therefore the s chamber must also through them communicate with the veins. In sup- f this, it was found by Schwalbe that both the spaces and the veins became with coloured fluid when this had been injected into the anterior chamber. blood does not find its way into the latter during life is not explained, since lves have as yet been discovered in these veins or spaces: the reason given that greater resistance is offered to its passage here than to its return e ordinary paths.

cording to Leber on the other hand, the results obtained by Schwalbe were o a diffusible colouring matter having been employed for filling the anterior ber. Leber affirms that when a non-diffusible one is used it never penetrates the canal of Schlemm, which is simply a large circular terminal vein, or a tion of two or three plexiform veins uniting at frequent intervals into one k. It is admitted however that fluid may pass with extreme readiness from nterior chamber into these veins.

essels and nerves.—In a state of health the cornea is not pro- d with blood-vessels, except at the circumference, where the capil- s of the conjunctiva and sclerotic end in loops. Neither are any phatic vessels discoverable, unless the channels in which the nerves , and which are lined with flattened cells and are indirectly in nection with the cell-spaces, are to be taken as representing them. *nerves*, on the other hand, are very numerous. Derived from the ry nerves, they enter the fore part of the sclerotic, and are from y to forty-five in number (Waldeyer). Continued into the fibrous of the cornea, they retain their dark outline for $\frac{1}{2\,0}$th to $\frac{1}{1\,0}$th of inch, and then, becoming transparent, ramify and form a plexus in laminated structure, near the anterior surface. From this *primary fundamental plexus* other nerves proceed, and passing obliquely ough the anterior homogeneous lamina, divide into pencils of fibrils, se general direction is towards the centre of the cornea, and which with one another to form a much finer and closer plexus at the face of the cornea, immediately beneath the epithelium. From this *ndary* or *subepithelial plexus* exceedingly fine, varicose, ultimate ils (fig. 333, *b*) pass among the epithelium-cells, and form here a d plexus or rather *network*, the *intra-epithelial* plexus, which ex- ds almost to the free surface (fig. 333, *c*, *c*), and the fibrils of ch end in minute terminal varicosities or knobs. According to Klein does not represent the ultimate ending, but the intra-epithelial ils are beset with minute ramifying processes, passing off at right les from them and forming a yet finer and closer network between epithelium-cells.

n addition to the nerves which are destined for the epithelium, rs, destined for the proper substance of the cornea, come off from the ary plexuses, and, after uniting into one or more secondary plexuses, cords of which are still composite, eventually form, in and among laminæ, a terminal network of ultimate fibrils, the meshes of which

are much more open than those of the intra-epithelial network (p 173, *c*, *d*, p. 173). An actual connection of these nerves with t puscles of the cornea has never been satifactorily shown; al since the fine nerve-fibrils run in the anastomosing cell-spac come into close connection with the corpuscles and their pr and have been described by some observers as being actually co with the latter.

The larger branches of the nerves are covered with a sheath tened cells which, as before mentioned, are in connection wi corpuscles of the cornea. At the points of junction of the p

Fig. 333.

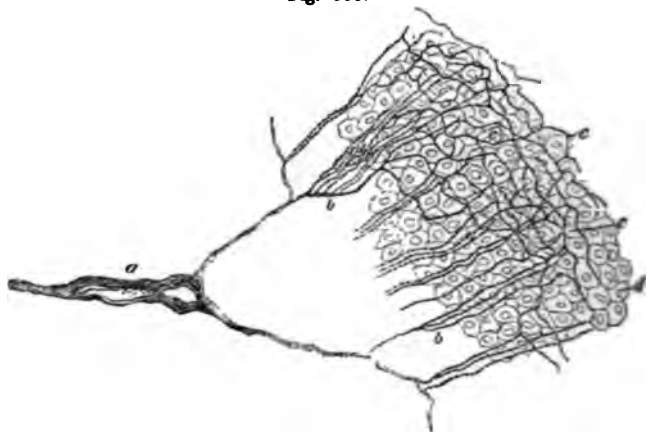


Fig. 333.—Termination of nerves in the rabbit's cornea. Chloride of preparation; oblique section (Klein).

a, part of the primary plexus in the substantia propria; *b*, fibrils of the sec (subepethelial) plexus; *c*, part of the tertiary (intra-epithelial) plexus (this is repre in the figure as much closer than is actually the case).

nuclei are frequently seen, but these appear to belong to the ensheat cells, and are not interpolated in the course of the fibres.

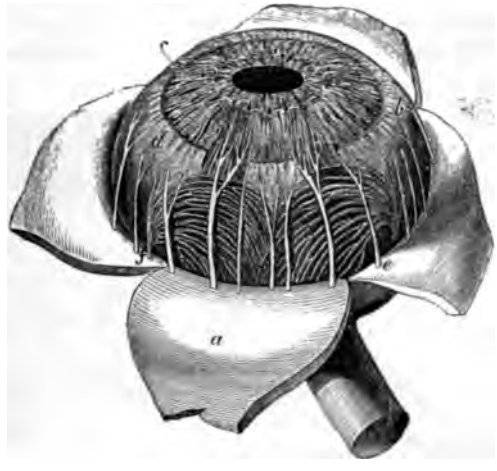
THE CHOROID COAT.

The **choroid coat** of the eye (tunica choroidea s. vasculosa) is a brown membrane lying between the sclerotic and the retina. Anteri it is continued into the iris, but before it passes into this it form number of radial inwardly projecting thickenings named ciliary p cesses, disposed in a circle and embedded in corresponding pit the surface of the vitreous humour and suspensory ligament of the l The choroid coat is thickest behind where it is pierced by the optic ne The outer surface is connected to the sclerotic by loose connective ti and by vessels and nerves which pass obliquely across a lymph-s which otherwise serves to separate the two tunics. The inner sur which is smooth, is covered by the hexagonal pigmented cells of retina. These, when the retina is detached, generally remain adhe to the choroid, and were formerly described as belonging to that c

[illegible]y are now known to be intimately related, both in their develop-[illegible]d also physiologically, to the retina.

Fig. 334.

[illegible]4.—Choroid mem-[illegible] and iris exposed [illegible] removal of the [illegible]otic and cornea [illegible] Zinn). Twice the [illegible]ral size.



[illegible]art of the sclerotic [illegible] back; *b*, ciliary [illegible]; *c*, iris; *e*, one of [illegible]iary nerves; *f*, one [illegible] vasa vorticosa or [illegible]al veins.

[illegible]e *ciliary processes* [illegible]335), about seventy [illegible]mber, are arranged [illegible]dionally, and to-[illegible]r form a circle. [illegible] consist of larger [illegible]maller thickenings [illegible]ut regular alterna-

Fig. 335.

[illegible]35.—Ciliary processes as seen from [illegible]ehind. Twice the natural size.

posterior surface of the iris, with the [illegible]ter muscle of the pupil; 2, anterior [illegible]f the choroid coat; 3, ciliary processes.

Each of the larger ones, mea-[illegible]g about $\frac{1}{10}$ of an inch in length [illegible]$\frac{1}{10}$ in depth, forms a rounded pro-[illegible]on at its inner (anterior) end, which [illegible]e from the pigment which invests [illegible]rest of the structure; but ex-[illegible]lly they gradually taper, and dis-[illegible]ar. The smaller processes are [illegible] half as deep as the others, and [illegible]t one-third as numerous. At [illegible] near the inner ends the processes are connected by lateral [illegible]ctions.

STRUCTURE OF THE CHOROID.

[illegible]e choroid consists mainly of blood-vessels united by a delicate con-[illegible]ve tissue, which contains numerous large ramified and pigmented

[illegible]ternally the choroid is bounded by a membranous layer similar to [illegible]*lamina fusca* of the sclerotic, and known as the *lamina supra-[illegible]idea*. This is composed of a thin membrane (or membranes) of a [illegible]geneous aspect, but pervaded by a network of fine elastic fibres, and [illegible]ed by large flat epithelium-like cells. It contains also large flat-[illegible] pigment-cells dispersed irregularly or arranged in patches, with [illegible]derable intervals free from pigment-cells; and lymphoid cells may

occur in it here and there singly or in groups (fig. 336). It is
united to the lamina fusca by vessels and bands of connectiv
enclosing pigment-cells, and the two laminæ as well as the
structures are coated with pavement-epithelium, a lymph-spac
thus formed between the sclerotic and choroid. This spac
municates, at the places where the vessels and nerves pierce the s
with that of the capsule of Tenon (Schwalbe).

Fig. 336.

Fig. 336.—A SMALL PORTION OF LAMINA SUPRA-CHOROIDEA. Highly ma
(E. A. S.)

p, pigment-cells; *f*, elastic fibres; *n*, nuclei of epithelioid cells (the outli
cells are not indicated); *l*, lymphoid cells.

The **choroid proper** resembles in general structure the lami
choroidea, but contains in addition a very large number of bloo
From a difference in the fineness of these constituent v
resolves itself into two strata, outer and inner; the former c
the larger branches, and the latter the capillary ramifications.
of connective tissue which unites the two strata, and is nearly
pigment, is sometimes described as a third or intermediate part

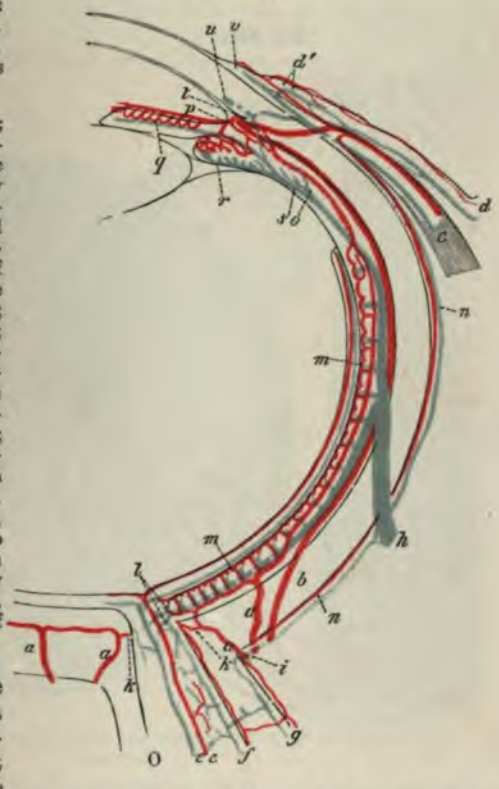
In the **outer part** of the coat are situated, as just stated,
branches of the vessels. The arteries (*short ciliary*) are comp
large and numerous, and piercing the sclerotic close to the op
(fig. 337, *a*), divide into branches which are directed at first
but soon bend obliquely inwards to end in the capillary laye
the veins (*vasa vorticosa*), external to the arteries, are disposed
as they converge to four or five principal trunks (fig. 334, *f*;
338, *h*) which pierce the sclerotic about half way between the
the cornea and the entrance of the optic nerve. In the interval
the vessels are elongated and stellate pigment-cells.

The **inner part** of the choroid coat (*tunica Ruyschiana s. ch
laris*, fig. 337, *m*) is formed mainly by the capillaries of the
vessels. From the ends of the arteries the capillaries radiate

rm meshes which are closer than in almost any other texture, ally fine at the back of the eyeball. The network reaches as as about $\frac{1}{8}$th of an inch from the cornea, or opposite the tina, where its meshes become larger, and join those of the sses.

GRAMMATIC RE-N OF THE COURSE KLS IN THE EYE. SECTION (Leber). ND CAPILLARIES BLUE.

Fig. 337.



of optic nerve; erior ciliary ar-nch to the optic posterior ciliary erior ciliary ves-ior conjunctival terior conjuncti-central vessels of vessels of the the optic nerve; e outer sheath; in; *i*, short pos-rein; *l*, anasto-idal vessels with erve; *m*, chorio-piscleral vessels; tery of the cho-s iridis major (in essels of iris; *r*, ary process; *s*, iliary muscle to *t*, branch from o anterior ciliary of Schlemm; *v*, at margin of

inner surface a Ruyschiana eless or fine-l transparent he *membrane* hich lies next to the pigmentary layer of the retina, and n the region of the ciliary processes, presents on its inner erous microscopic reticular folds.

ry processes have the same structure as the rest of the t the capillary plexus of the vessels is less fine, and has chiefly a longitudinal direction; and the ramified cells, mber, are devoid of pigment towards the free extremities of

-vessels of the ciliary processes (fig. 340, *d*) are very numerous, ved from the anterior ciliary (fig. 337, *c*) and from those of of the choroidal membrane. Several small arterial branches ter part of each ciliary process, at first running parallel to nd communicating sparingly. As they enter the prominent on, the vessels become tortuous, subdivide minutely, and equently. Finally they form short arches or loops, and turn

backwards to pour their contents into the radicles of the vei
free border of the fold, one artery, larger than the rest, exten
length of each ciliary process, and communicates through
vessels with a long venous trunk which runs a similar co
attached surface.

Ciliary muscle.—At the anterior part of the choroid, be
the sclerotic, is a zone of plain muscular tissue, the *cilia*

Fig. 338.

Fig. 338.—Semi
REPRESENTATI
COURSE OF TI
THE CHOROID A

The ciliary r
posed to be re
right side to sh
of the ciliary pr
converging vesse
zone.

Bowman. It
332, 10) by a
from the for
sclerotic close
nea, between
Schlemm and
of Fontana, a
spreading out,
backwards (fi
to be inserte
choroid oppo
ciliary proc
partly further
their insertio
pass equatori
ter-cross so
peculiar stell
According to
a small po
outermost) i
inserted into the sclerotic coat (fig. 332, M). These antero-
meridional and radiating fibres, pass at the side next the iris
fibres (L), which have a circular course around the insertio
This set forms the *circular ciliary muscle* of H. Müller.
muscle is much developed in hypermetropic eyes, but is
may even, it is said, be absent in myopic (Iwanoff). The ci
at least its inner part, was formerly described as the *ciliary l*
birds the ciliary muscle is composed of cross-striped muscul

The *nerves* of the choroid will be described with those of the iri

THE IRIS.

The **iris** is the contractile and coloured membrane v
behind the transparent cornea, and gives the tint to the
centre it is perforated by an aperture—the *pupil*.

At its circumferential border, which is nearly circula

ions with the choroid, and by the ligamentum pectinatum, with nea: the free inner edge is the boundary of the pupil. The iris es half an inch across, and, in a state of rest, about one-fifth of h from the circumference to the pupil. The anterior surface, ly coloured in different eyes, is marked by waved lines converging s the pupil, near which they join in a series of irregular eleva- and, internal to these, other finer lines pass to the pupil. The or surface is covered with dark pigment, and is marked by a r of fine converging folds or thickenings prolonged from the processes.

Fig. 339.

Fig. 340.

g. 339.—Injected blood-vessels of the choroid coat (from Sappey). 30 diameters.

ne of the larger veins; 2, small communicating vessels; 3, branches dividing into nallest vessels.

340.—Vessels of the choroid, ciliary processes, and iris of a child (Arnold) Magnified 10 times.

capillary network of the posterior part of the choroid, ending at *b*, the ora serrata; eries of the corona ciliaris, supplying the ciliary processes, *d*, and passing into the ; *f*, the capillary network close to the pupillary margin of the iris.

he **pupil** is nearly circular in form, and is placed a little to the r side of the centre of the iris. It is constantly varying in size ng life, the variation ranging from $\frac{1}{20}$th to $\frac{1}{3}$rd of an inch, and lating the quantity of light admitted to the eyeball. It is habitually r in young than in old persons.

STRUCTURE OF THE IRIS.

delicate connective tissue forms the framework of the iris, and ent cells are scattered through the texture. It contains also erous vessels and nerves. The epithelial layer of the membrane of

Descemet (fig. 332, 2) is continued from the margin of the co
the front of the iris ; its cells are smaller and more granular
which cover the membrane of Descemet, but are otherwise sim

The **stroma** consists of cells and fibres of connective tissue
directed for the most part radially towards the pupil.

In the substance of the iris anteriorly and throughout it
are variously-shaped ramified pigment cells like those in t
The pigment contained in them is yellow, or of lighter or da
of brown, according to the colour of the eye. At the poste
is a covering of dark pigment, the *uvea* of authors ; this is
with the (retinal) pigmentary layer lining the ciliary process
consists of several strata of small roundish cells filled with bla
granules. The colour of the iris depends on the pigment in
cells ; in the different shades of blue eye it arises from the bl
of the posterior surface appearing more or less through
which in such cases is only slightly coloured or is colourless
black, brown, and grey eye, the colour is due to the p
scattered through the substance of the stroma itself.

The **muscular tissue** is of the non-striated kind, and is
a ring (*sphincter*) around the pupil, and as rays (*dilatato*
sphincter to the circumference.

The *sphincter* (fig. 341, *a*) is a narrow band about $\frac{1}{20}$
wide, situated close to the pupil posteriorly. Near the m

Fig. 341.

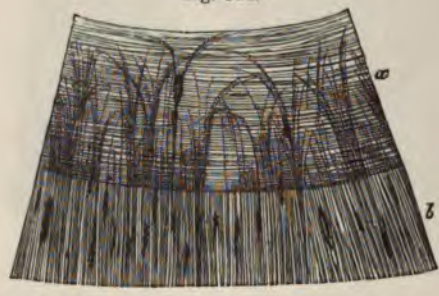


Fig. 341.—SEGMENT
SEEN FROM THE
FACE AFTER REM
UVEAL PIGMENT (

a, sphincter musc
muscle of the pupil.

pupil the fibre
together, but th
fibres are more
and form les
rings.

The *dilatato*
apparent than th
begins at the ciliary or outer margin of the iris, and its fib
a continuous membrane close to the posterior surface, conv
the pupil. Here they bend round and blend with the sph
reaching nearly to its inner margin. At their origin at
margin, they also arch round and take a somewhat circular

Vessels of the iris.—The *long ciliary arteries*, two in nu
the sclerotic a little in advance, and one on each side, of the
Having gained the interval between the sclerotic and ch
they extend horizontally forwards (figs. 337, 338, *b*, fig. 342
by loose connective tissue to the ciliary muscle. In this co
nearly in the horizontal plane of the axis of the eye-ball, the
being however a little above, and the inner one a little below
that line. A little behind the attached margin of the iris
divides into an upper and a lower branch, and these, anasto
the corresponding vessels on the opposite side and with
ciliary, form a vascular ring (*circulus major*, fig. 338, *p*, fig. 3

on. From this circle small branches arise to supply the ciliary
; whilst others converge towards the pupil, and there, freely com-
ating by transverse offsets from one to another, form a second circle
astomosis (*circulus minor*), from which capillaries are continued
lly and end in small veins.

anterior ciliary arteries (fig. 337, *c*, fig. 342, 2, 2), five or six in
r, but smaller than the vessels just described, are supplied from
uscular and lachrymal branches of the ophthalmic artery, and
the sclerotic about $\frac{1}{12}$th of an inch behind the margin of the
; they divide into branches which supply the ciliary processes,
n the circulus major.

Fig. 342.

.—FRONT VIEW OF OOD-VESSELS OF THE D COAT AND IRIS BEFORE (Arnold). FIED 2½ TIMES.

oid; B, iris; C, cili-
scle; 1, 1, long
eries; 2, 2, five of
ior ciliary arteries
at the outer margin
is; 3, loop of com-
n between one of
ior and one of the
y arteries; 4, inter-
and network of the
the iris; 5, external
work of vessels.

les these special
, numerous mi-
essels enter the
om the ciliary
es.

veins of the iris follow closely the arrangement of the arteries
scribed. The canal of Schlemm communicates with this system
ls.

ves of the choroid and iris.—The *ciliary nerves* (fig. 334),
fifteen in number, and derived from the lenticular ganglion and
sal branch of the ophthalmic division of the fifth nerve, pierce
erotic near the entrance of the optic nerve, and come immediately
ntact with the choroid. They are somewhat flattened in form, are
embedded in grooves on the inner surface of the sclerotic, and
nicate occasionally with each other before supplying the cornea
tering the ciliary muscle. When the sclerotic is carefully separated
he subjacent structures, these nerves are seen lying on the surface
choroid, into which they send branches, and in which they form a
ated plexus amongst the blood-vessels, the groups of ganglion-cells
often applied to the walls of the vessels. Within the ciliary muscle
rves also subdivide minutely, forming here another plexus, which
ns a number of medullated fibres, and the cells of which are
r. A few recurrent branches appear to pass back from it into the
d coat, but the greater number pass on to the iris (fig. 343, *a*, *a*).
iris the nerves follow the course of the blood-vessels, dividing
ranches, which communicate with one another as far as the pupil,

forming a close plexus of fine non-medullated fibres. Their ultimate destination is probably the muscular tissue of the iris and of its vessels.

Fig. 343.

Fig. 343. — Distribution of nerves in the iris (Kölliker). 50 Diameters.

The preparation was from the eye of an albino rabbit; *a*, smaller branches of the ciliary nerves advancing from the choroid; *b*, loops of union between them at the margin of the iris; *c*, arches of union in the iris; *c'*, finer network in the inner part; *e*, sphincter pupillæ muscle.

THE RETINA.

The retina is a delicate membrane, which contains the expanded termination of the optic nerve. It lies within the choroid coat, and rests on the hyaloid membrane of the vitreous humour. It extends forwards nearly to the outer edge of the ciliary processes of the choroid, where it ends in an indented border, named *ora serrata*. From this border there is continued onwards a thin layer of a different structure and containing no nerve-fibres, the *pars ciliaris retinæ*, which reaches as far

Fig. 344.

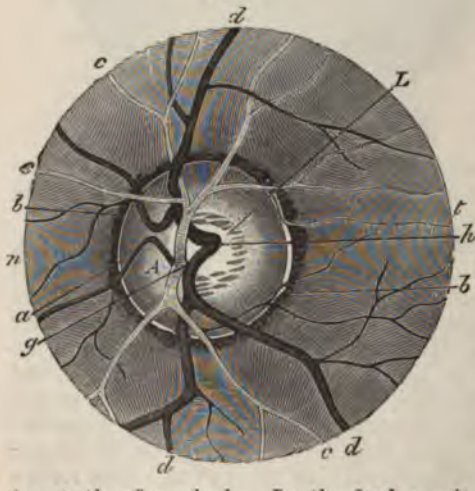


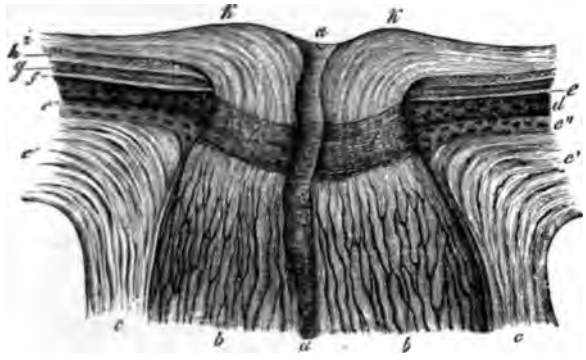
Fig. 344. — The back of the retina with the point of entrance of the optic nerve as seen with the ophthalmoscope (E. Jaeger).

A, optic nerve, passing through the lamina cribrosa, L, which shows through the disk-like expansion of the entering nerve; *a*, ring of connective tissue; *b*, choroidal ring; *c*, branches of the central artery of the retina, *g*; *d*, branches of the central vein, *h*; *n*, inner or nasal side; *t*, outer or temporal side.

as the tips of the ciliary processes, and there gives place to the uveal pigment, which is continued on to the posterior surface of the iris. The thickness of the retina diminishes from behind forwards, from $\frac{1}{50}$th to $\frac{1}{200}$th of an inch. In the fresh eye it is translucent and of a light pink colour, but of a purple-red colour if carefully shaded from the light for a little while before removal. Under the influence of sunlight however it is quickly bleached and after death it soon becomes opaque. Its outer surface is covered with a layer of hexagonal pigment-cells which, as the study of the development of the parts shows, must be regarded as belonging to the retina and not to the choroid, to which it has usually been ascribed. Moreover the pigment-cells send fine offsets

[redacted] the external retinal elements. When the choroid is detached [redacted] offsets are ruptured and the pigmentary layer comes away with it. [redacted] inner surface of the retina is smooth: on it the following objects [redacted] be seen. In the axis of the ball is a yellow spot—*macula lutea* (*limbus* [redacted], Sömmerring)—which is somewhat elliptical in shape (fig. 347, *b*), [redacted] about $\frac{1}{20}$th of an inch in diameter: in the centre of this, again, is a [redacted] hollow, *fovea centralis*, and, as the retina is thinner here than elsewhere, the pigmentary layer is clearly visible through it, giving rise to an [redacted] arance as of a hole through the tunic. About $\frac{1}{10}$th of an inch

Fig. 345.



345.—SECTION THROUGH THE MIDDLE OF THE OPTIC NERVE AND THE TUNICS OF THE EYE AT THE PLACE OF ITS PASSAGE THROUGH THEM (altered from Ecker). [redacted]

[redacted] arteria centralis retinæ; *b*, fasciculi of optic nerve fibres; *c*, dural sheath of the optic [redacted], passing into *c'*, the sclerotic coat; *c''*, membrana fusca; *d*, choroid; *e*, *f*, layer of [redacted] and cones; *g*, the nuclear layers; *h*, layer of nerve-cells; *i*, layer of nerve-fibres; [redacted] colliculus or eminence at the entrance of the optic nerve; *l*, lamina cribrosa.

[redacted]de the yellow spot is the round disc, *porus opticus* (fig. 344, A; fig. [redacted]7, *a*), where the optic nerve pierces the retina and expands to form [redacted] inner layer. At this place the nervous substance is slightly elevated [redacted] as to form an eminence (*colliculus nervi optici*) (fig. 345, K, K), and [redacted] its centre is the point from which the vessels of the retina branch.

[redacted] When examined during life by the aid of the ophthalmoscope, the optic disc [redacted]pears of a light grey tint, contrasting strongly with the colour of the rest of [redacted] field (see fig. 344).

MICROSCOPIC STRUCTURE OF THE RETINA.

When vertical sections of the retina, *i.e.*, sections made perpendicularly to its surface, are submitted to microscopic examination, eight distinct strata are recognizable, together with certain fibrous structures which pass vertically through the membrane and connect the several layers.

The following are the designations of the layers, from within outwards:

1. The layer of nerve-fibres (nerve-layer).
2. The layer of nerve-cells (ganglionic layer).
3. The inner molecular layer.
4. The inner nuclear layer.

5. The outer molecular layer (internuclear).
6. The outer nuclear layer.
7. The layer of rods and cones (columnar layer).
8. The layer of hexagonal pigment cells (pigmentary layer).

Fig. 346.

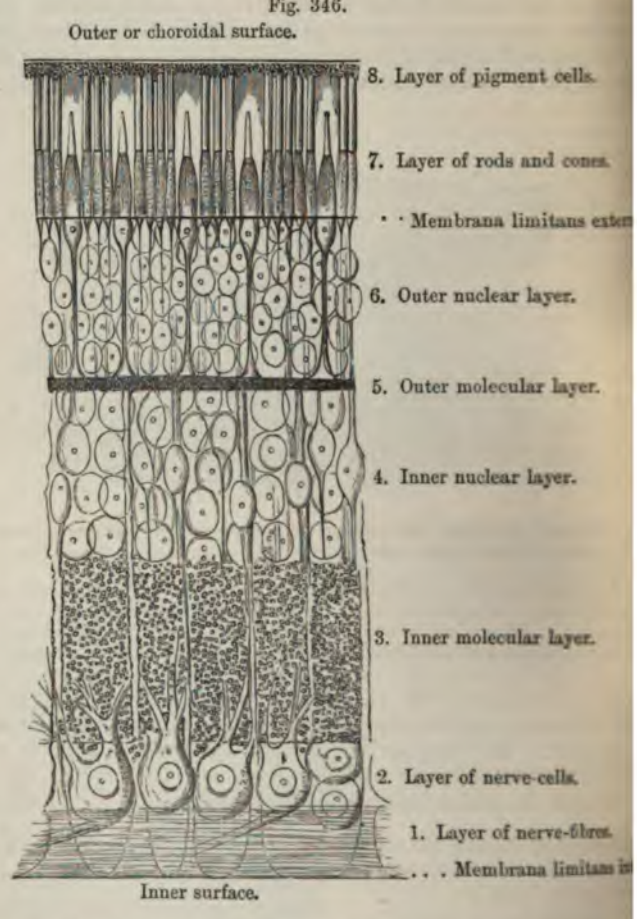


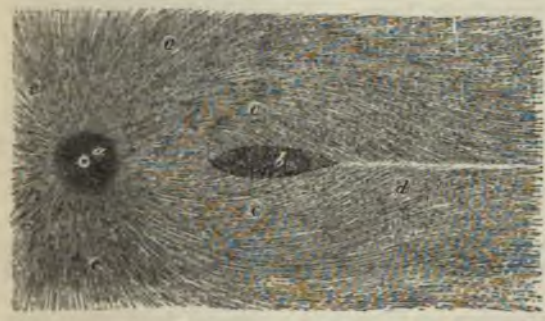
Fig. 346.—Diagrammatic section of the human retina (Schultze).

In addition to these eight strata two very delicate membran described—the one, *membrana limitans interna*, bounding the reti its inner surface, next to the hyaloid membrane of the vitreous hu the other, *membrana limitans externa*, lying between the outer n layer and the layer of rods and cones; but, as will be after explained, these so-called "membranes" are merely the boundary of the sustentacular tissue of the retina. The accompanying from Max Schultze, represents (somewhat diagrammatically) the g arrangement and structure of the layers. The several layers retina will first be considered successively as they are met with

out, after which the sustentacular fibres or fibres of Müller which
several of the layers will be described, and finally an account
given of those parts of the retina which present points of
ce from the rest, especially the central fovea, and the ciliary

ayer of nerve-fibres.—The optic nerve (fig. 345, *b b*) passes at
us opticus directly through the thickness of the retina to reach its
rface, on which it spreads out in the form of a membrane (fig. 347)
extends to the ora serrata. Its fibres, which are destitute of a
ve sheath and vary much in size but are mostly small, lose
medullary sheath on reaching the retina, consisting there of
linder only (Bowman). They are collected into small bundles,
compressed laterally, intercommunicate and form a delicate
ith narrow elongated meshes. At the yellow spot this layer is
wanting (fig. 347, *b*), but elsewhere it forms a continuous stratum,
lly diminishing in thickness in front, interrupted only by
arged ends of the fibres of Müller to be afterwards described
6, 1). The nerve-bundles, as well as the cells of the next layer,

Fig. 347.



7.—PART OF THE LAYER OF NERVE-FIBRES ON THE INNER SURFACE OF THE RETINA (Kolliker). MAGNIFIED.

lliculus opticus; *b*, yellow spot; *c*, *d*, bundles of nerve-fibres passing round
, *e*, bundles radiating in all directions from the point of entrance of the nerve.

rtially covered and supported by flattened cells like those met
in the interstitial tissue of the nervous centres and probably
ging to the connective tissue.

Ganglionic layer.—Immediately external to the nerve-fibre layer
tratum of nerve-cells (fig. 346, 2), of a spheroidal or pyriform
, and having in the fresh condition a pellucid aspect. Each cell
single unbranched process extending obliquely from its rounded
extremity amongst the fibres of the preceding layer, with one of
it is no doubt continuous. From the opposite end of the cell,
is frequently imbedded in the granular substance of the succeeding
one or more much thicker processes extend outwards for a variable
ce into that stratum, and after branching dichotomously once or
become lost in its substance. The number of nerve-cells and
quently the thickness of the ganglionic layer in the different
s of the retina varies exceedingly. Over the greater part of the
they form a single stratum, but in the neighbourhood of the

yellow spot they are placed two or three deep. At the
(fig. 355, 2) they are very thickly set (from eight to ten deep)
are also much smaller here, and are bipolar. Towards the o
on the other hand, there is but a single stratum, and that
incomplete.

3. **Inner molecular layer.**—Next in order to the ganglionic l
a comparatively thick stratum of a granular-looking substanc
the hardened retina exhibits, under high powers of the micr
appearance of a network or spongework of fine homogeneous trab
reticulated interstices, occupied probably by lymph (Retzius).
stance presents both in the fresh and hardened condition a c
resistance to the action of chemical re-agents. The fibres of l
through this layer without being directly connected with its
the offsets of the ganglion-cells can also be traced into it fo
or less distance; and, lastly, the fine, varicose central proce
nuclear bodies of the layer next to be described can be follow
distance into it (fig. 350), passing in the direction of the
and nervous layers. Flattened cells, similar to those noti
nerve-fibre and ganglionic layers, are also said to occur in
molecular layer, especially on its surfaces (Golgi and Manfred

4. **Inner nuclear layer.**—This is mainly composed of
of characteristic transparent nucleus-like bodies, which are
known collectively as the "inner granules," but are of thr
distinct kinds. Those of the *first* kind, by far the most
(fig. 350,4), are round or oval clear bipolar cells, prolonged at
into a delicate fibre, the cell being almost entirely occupied by
of corresponding shape, with a distinct nucleolus. These
nucleus and nucleolus) resemble very closely the analogous
found in ganglion-cells, and indeed the bodies in question are
regarded as nerve-cells, but with the protoplasm of the cell ver
amount, devoid of granules, and principally collected at either
nucleus.

Of the processes or fibres which proceed from these cells,
one, or that extending into the inner molecular layer towards
glionic and nerve-fibre layers, is finer than the other, is always un
and generally exhibits minute varicosities similar to those on th
fibrils of the nerves. A direct connection of these inner proc
the outwardly extending branches of the large nerve-cells of
glionic layer has not been completely substantiated; but it is c
probable that some of them may be so connected, while others
directly to the nerve-layer and there become continued into
fibre. The outer prolongation or process of the bipolar c
varicose, is thicker than the inner one, and in some ca
undivided into the next layer, in others divides into branc
in this or before reaching it. The further destination of th
will be afterwards referred to.

The relative length of the inner and outer process naturally differ
to the position of the individual cell in the nuclear layer; if the cell
inner molecular layer the outer process will have a longer course t
outer molecular layer, and, conversely, if the cell is near the latter
all cases, however, the inner process is the longer of the two, as
before mentioned, for some distance into the contiguous molecular
the macula lutea these processes or fibres of the inner nuclear la

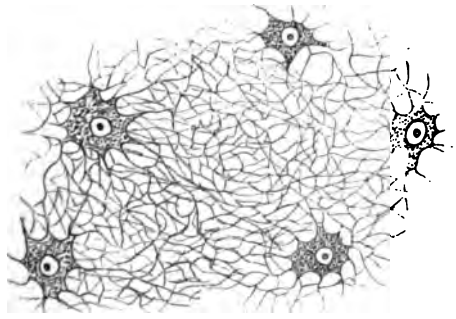
oblique direction, in other parts of the retina they run vertically
surfaces.

ond kind of "inner granule" is entirely different from those
ibed. The cells are devoid of processes, and are more proto-
they are exclusively collected at the innermost part of the
ear layer, where in man they form a nearly complete stratum
an), and they perhaps bear some relationship to the inner mo-
er, but further investigations are required as to their nature.
remark will apply to certain other cells which constitute a *third*
ed variety of the inner granules, and which occur here and there
rmost part of the layer. They are distinguished from the ordi-
ner granules" by their rounded form and larger size, and also,
to W. Krause, in possessing only one process—an inner one
e regards as a terminal nerve-fibre.

the fibres of Müller, as they traverse this layer, are connected
nuclei which more especially belong to those fibres and will be
with them.

er molecular layer.—The outer molecular layer is much
an the inner, but otherwise presents, in vertical sections of
retina, a similar granular appearance, with a few scattered
its substance, and in which, in the human retina and in that of
mals, it is difficult to make out any definite structure. In the
tina, however, as Rivolta and others have shown, it is possible
y prepared and isolated portions of the layer to ascertain the
within it of flattened, irregular or stellate, finely branched,
granular cells to which the nuclei in question belong

Fig. 348.



— BRANCHED
TH THE UNITING
K OF FIBRES
IN OUTER MO-
LAYER OF
ERR'S RETINA
e). HIGHLY
ED.

). The cell-
hich are ex-
y fine, form
ated branch-
union a close
or feltwork
out the layer,
tance of which
s way formed

a. The nuclei of the cells are clear and distinct, each with a
atively large nucleolus; the fine fibres of the network are stated
i and Manfredi to exhibit varicosities like nerve-fibrils, but accord-
chwalbe the varicose fibrils in all probability do not actually form
the network, but are intercalated in its meshes. It is, therefore,
n whether these cells are to be regarded as of a nervous nature
es or merely as supporting structures for the true nervous
s. There is little doubt that a similar structure exists in
ls generally.

layer receives the outwardly directed processes of the bipolar

inner granules, and these probably become connected within i from the rods and cones.

The layers hitherto described contain structures (cells and fibres) wh doubtedly of nervous nature, and which appear to be developed in manner as corresponding structures in the brain. The two next to b are of epithelial nature, and constitute collectively what is sometime the nerve-epithelium of the retina, in contradistinction to the ne nervous or cerebral part. The two layers (outer nuclear and co morphologically but one, being composed of long cells, which exte both layers. Each cell is drawn out into a fibre, and furnished with in its inner portion, (rod- or cone-fibre and its outer granule), and i modified both in shape and structure in its external portion (ro proper).

6. **Outer nuclear layer.**—This (figs. 346, 350, 6) resem closely at first sight the inner nuclear layer, appearing, like thi sist of several strata of clear, oval or elliptical, nuclear corpus granules), from the ends of which delicate fibres are prolonge outer granules differ, however, essentially from the inner gra may be readily distinguished from them. They are of two kin present well-marked differences, and are known respectively a granules and cone-granules, accordingly as they are connected rods or with the cones of the next retinal layer. Those which nected with the *rods* are, in most parts of the retina, by far numerous, and form the main thickness of the outer nuclear lay may be regarded as enlargements or swellings in the course o

Fig. 349.

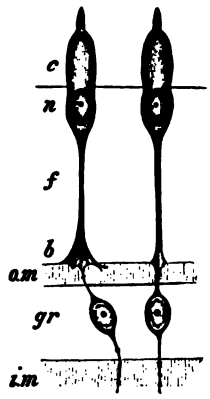


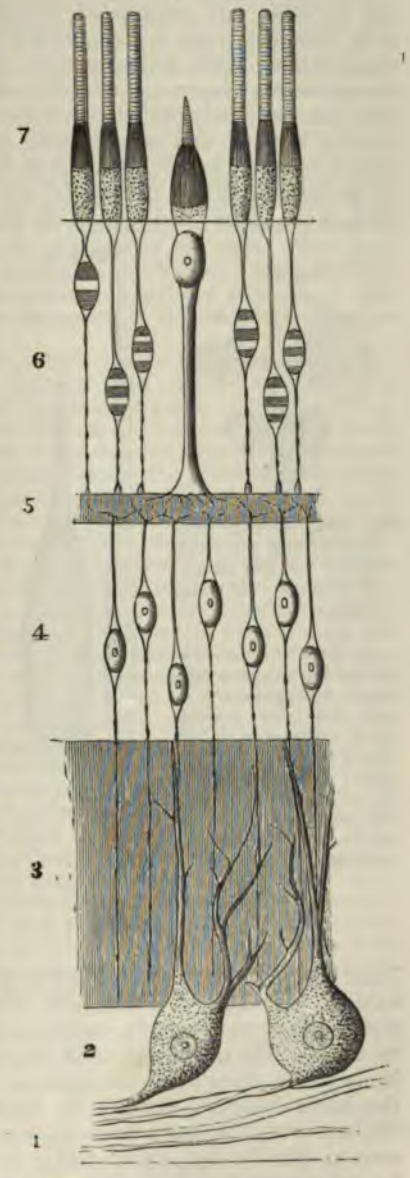
Fig. 349.—CONNECTION OF INNER GRA A BASE OF CONE-FIBRES (after Gunn). E NIFIED.

c, cone ; *w*, cone-nucleus ; *f*, cone-fi base ; *gr*, inner granule ; *om*, outer mole The left hand figure indicates a probable between the base of a cone-fibre and an in on the one hand ; and on the other h same inner granule and a process of a ro *im*, inner molecular layer.

fibres (rod-fibres), which extend inner ends of the rods at the m limitans externa through the thi this layer to the outer molecular la enlargements, of which there is b a fibre, situate at any part of it are each occupied by an elliptical and, in the fresh condition, exh markable cross-striped appearance (Henle), the strongly r substance which mainly composes the enlargement being in by bands or disks of a clearer less refracting material, usuall number, one on each side of the middle line (fig. 350), l sionally single and median (see the left-hand one in fig. 35 rod-fibres are of extreme fineness, and exhibit minute v in their course: each is directly continuous at the o with one of the rods, but at the inner end appears usually to in a somewhat larger varicosity, from which one or more fine f be traced extending into the substance of the outer molecu

are probably connected with the processes of the inner granules, ıe connection has not been satisfactorily proved.

Fig. 350.



50.—THE NERVOUS AND EPITHELIAL ELEMENTS OF THE RETINA (SEMIDIAGRAMMATIC). After Schwalbe.

numbers are the same as in fig. 346. xtent of the molecular layers is ed merely by linear shading.

ose outer granules which are ected with the *cones* are, in parts of the retina, much in number than the rod-ules, from which they are guished by their shape, n is somewhat pyriform, by bsence of transverse striation, by their position—for they py the part of the outer nu- layer nearest the membrana ans externa, and the larger of each is thus in close proxi- to the base of the correspond- one (fig. 349), with which it rectly connected, or there is at a short, comparatively thick uniting the two (see fig. 350). the macula lutea, however, re only cone-granules are met , many of them are further oved from the limiting mem- ne, and the stalk is then longer more attenuated. The nucleus ach, which, as in the case the rod-granules, occupies ost all the enlargement, con- s a distinct nucleolus. The e-fibre is very much thicker n the rod-fibre above de- bed, and may itself appear ly striated or fibrillated. It ses from the smaller end of the r-shaped enlargement straight ough the outer nuclear layer each the outer molecular layer, n which it rests by a some- at pyramidal base, from the es of which fine processes y be traced into the substance the molecular layer; one at st of these processes has been shown by Gunn to be continuous with the er or peripheral process of an inner granule (fig. 349). According to rkel the processes abut against one another without being continuous.

7. **The layer of rods and cones.** The elements whic this layer are, as their name implies, of two kinds, th one kind—the *rods*—having an elongated cylindrical form; on the other hand being shorter, much thicker, bulged at end or base, and terminated externally by a finer taperin Both rods and cones are closely set in a palisade-like manne whole extent of the retina between the membrana limitans e the pigmentary layer (fig. 346, 7). Except at the macula l only cones are met with, the rods far exceed the cones in num relative number and arrangement is well exhibited when t viewed from the outer surface, as in fig. 351, where *a* represent of the layer from the macula lutea; *b*, from the immediate hood of the latter; and *c*, from the peripheral part of the reti

Fig. 351.

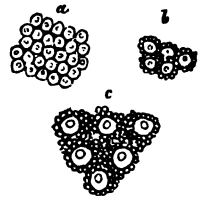


Fig. 351.—OUTER SURFACE OF THE COLUMNAR LAYER OF THE RETINA (Kölliker). 350 DIAMETERS.

a, part within the macula lutea, where only cones are present; *b*, part near the macula, where a single row of rods intervenes between the cones; *c*, from a part of the retina midway between the macula and the ora serrata, showing the preponderance of the rods.

Fig. 352.

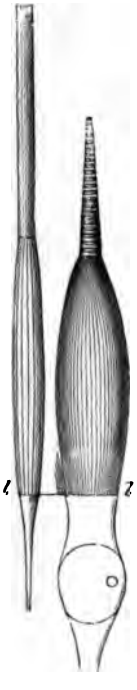


Fig. 352.—A ROD AND A THE HUMAN RETINA (M HIGHLY MAGNIFIED.

In the rod the longitud of both the outer and inne shown; in the cone the tra tion of the outer segment s tudinal of the inner segment externa.

The rods and the though differing thus and size, agree in many structure. Thus, eac of two distinct segm inner and an outer; th between the two occur case of the rods, about t of their length (in ma cones at the junction o tapering end-piece with part; consequently, the inner segments of the nearly similar in size a the inner being, howeve bulged, whereas the inne of each cone far exceeds one in size, the latter merely as an appenda inner segment (fig. 352). The two segments both of the rods exhibit well-marked differences, both in their chemical an characters, as well as in the structural appearances which may b in them. Thus, while in both the outer segment is doubly in its action upon light, the inner is, on the contrary, singly re the inner becomes stained by carmine, iodine, and other fluids, whilst the outer remains uncoloured by these reagent stained darkly by osmic acid. The outer segment in bo a tendency to break up into a number of minute superimp whereas the inner segment is itself again distinguishable into tw an outer part, composed, according to Max Schultze, of fine f an inner part, homogeneous, or finely granular, and, at the

longed into fine, straight, filamentous processes (fig. 353, *b*), whi
for a certain distance between and amongst the outer segmen
rods and cones—indeed the outer parts of the rods may be s
altogether embedded in the pigment-cells (*c*).

Fig. 353.

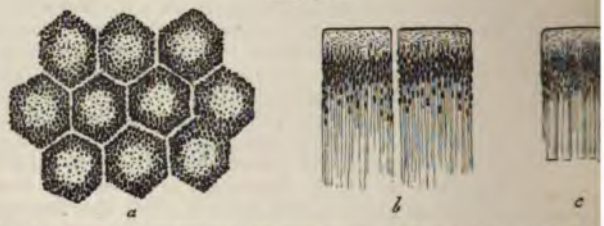


Fig. 353.—PIGMENTED EPITHELIUM OF THE HUMAN RETINA (Max Schultze) MAGNIFIED.

a, cells seen from the outer surface with clear lines of intercellular substanc
b, two cells seen in profile with fine offsets extending inwards; *c*, a cell still
tion with the outer ends of the rods.

The pigment granules, many of which are in the form of minute cr
placed for the most part, both in the cells and cell-processes, with
axes at right angles to the surface of the retina. The distribution o
ment granules within the cells varies during life and immediately aft
of the eye, according as the retina has been shaded from the light or
its influence. In the former case the pigment is mainly accumula
body of the cell (or at least its inner zone), and is withdrawn to a gr
from between the rods; but after exposure to light, a large amount o
is found between the rods, and some of the granules may even extend
the external limiting membrane. The pigment appears to have the
of renewing the colour (visual purple) of the outer segments of the
these have become bleached from exposure to the light. This renew
colour will take place for a short time after the death of the anim
excision of the eye (Kühne).

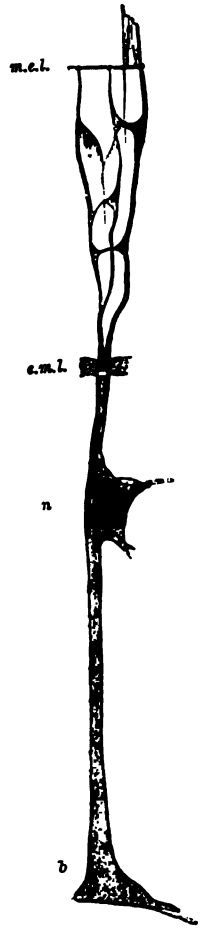
In some animals coloured oil-droplets occur in the non-pigmented
the cells.

The intervals between the rods and cones are only partially fille
processes of the hexagonal pigment-cells; the remaining part appe
occupied by a clear substance, which, according to Henle and H. Müll
soft elastic consistence during life and in the fresh condition, but soon
after death; but according to Schwalbe, is normally liquid. In the
between the hexagonal pigment and the remainder of the retina, there is
cleft filled with fluid (remains of cavity of primary optic vesicle).

The sustentacular tissue of the retina: Müllerian or fibres.—In addition to the elements which belong specially to th
above described, there are certain other structures which are con
nearly all the layers, passing through the thickness of the retina f
inner almost to the outer surface, and, if not actually of the natur
nective tissue, at least serving the same kind of purpose, namely, to
gether and support the more delicate nervous structures of the me
These *sustentacular fibres* or *fibres of Müller* (fig. 354), commenc
inner surface of the retina by a broad conical hollow base or foot,
filled by granular substance, and often contains a nucleus-like bo
bases of adjoining fibres are united together at their edges,
give, in vertical sections of the retina, the appearance of a

ry line (fig. 346); this has been named *membrana limitans in-*
ut, as may be inferred from the above description, it is in no way
nuous or independent membrane. The Müllerian fibres pass
h the nerve- and ganglionic layers, either with a smooth contour,
but two or three well-marked lateral projections from which fine
r processes extend amongst the elements of these layers: gradu-
minishing in size they then traverse the inner molecular layer,
, according to Schwalbe, becoming actually connected with the
nce which mainly composes it, although in the mammalian retina
bres may be marked by slight projections in passing through this

Fig. 354.



354.—A FIBRE OF MÜLLER FROM THE HUMAN RETINA, ISOLATED (from Henle). $\frac{1000}{1}$

ne of the fibre; *n*, its nucleus; *m.e.l*, membrana limi-
terna; *e.m.l*, external molecular layer.

In the inner nuclear layer they again give
elicate flattened processes from their sides,
t pass round the inner granules and serve
pport them. Moreover, each Müllerian fibre
re characterised by the presence of a clear
r elliptical nucleus (already mentioned in the
ption of the inner nuclear layer), containing
cleolus, and situated at one side of, and in
adherence to the fibre to which it belongs (fig.
3). On reaching the outer nuclear layer (after
ng through the outer molecular) the fibres of
r break up into fibrils and thin lamellæ, and
s form they pass outwards through the layer,
een the outer granules and the rod and cone-
, more or less enclosing these structures, filling
e intervals between the granules and forming
al sheaths for them. At the level of the
l or central ends of the cones and rods, the
erous offsets terminate along a definite line
h marks the boundary between the outer
ear layer and the layer of rods and cones, and
been termed *membrana limitans externa*. This
like the *m. l. interna*, is in no way a continuous
brane, nor is it isolable from the Müllerian
s; indeed, numerous fine fibrillar offsets of
s pass a short distance beyond the so-called
ing membrane, and closely invest the bases of
inner segments of the rods and cones. Accord-
o some accounts a delicate membrane prolonged
the limitans externa completely invests each
and rod.

he Müllerian fibres exhibit a fine striation.
r swell up and become indistinct on treatment
acetic acid and dilute alkalies, but much more
y than connective tissue fibrils; moreover,
are not dissolved by boiling in water. They are much less developed
e central and posterior part of the retina than in the peripheral and
ior part; towards the ora serrata they are very distinct and closely set.

Structure of the macula lutea and fovea centralis (fi
The peculiarities in structure which these present have been fo
part incidentally noticed in the preceding description of t
layers. In the fovea no rods are met with, and the cones
longer and narrower than elsewhere. All the other layers
thinned, but towards the margin of the fovea they rapidly i
thickness, and in the rest of the macula lutea most of them a
than at any other part of the retina. The ganglionic layer (fi
is especially thickened, the cells being from six to eight de
and placed rather obliquely. The nerve-fibre layer (1) gradu
towards the edge of the fovea as the fibres dip in to join t
ends of the bipolar ganglion-cells. The peripheral proces

Fig. 355.

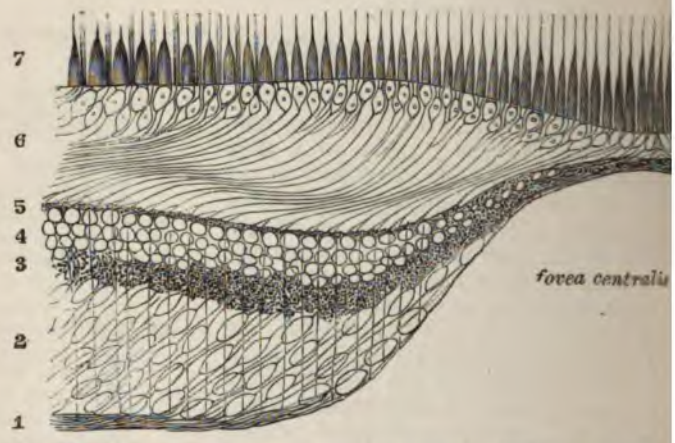


Fig. 355.—VERTICAL SECTION THROUGH THE MACULA LUTEA AND FOVEA DIAGRAMMATIC (after Max Schultze).

1, nerve-layer; 2, ganglionic layer; 3, inner molecular; 4, inner nucle
outer molecular layers; 6, outer nuclear layer, the inner part with only cone-
ing the so-called external fibrous layer; 7, cones and rods.

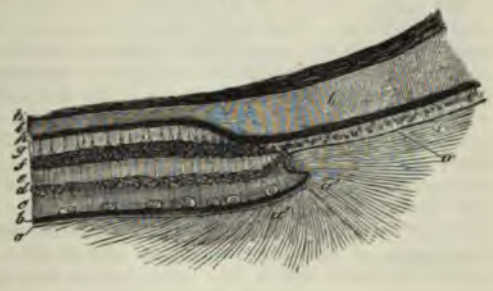
ganglion-cell is said to bifurcate, each branch becoming conne
a granule of the inner nuclear layer (Merkel). The inner gra
also somewhat obliquely disposed, are large, and near the botto
fovea, where this layer and that of the nerve-cells run together,
hardly be differentiated (Hulke). The outer nuclear laye
occupied in the greater part of its thickness by the very l
obliquely disposed cone-fibres; the nuclei are only two or three
take up a comparatively small portion of the layer.

The yellow tint of the macula is deepest towards the centre:
to a diffuse colouring matter which is seated in the interstices
the elements of the four or five inner layers.

Structure of the ora serrata and pars ciliaris.—At
serrata the numerous complex layers of the retina for the m
disappear, and in front of the ora serrata, the retina is re
merely by a single stratum of elongated columnar cells with
mentary layer external to it (*pars ciliaris*). The transition is
somewhat abrupt, all the changes being met within a zone of

inch only in breadth. The layer of rods and cones (fig. 356, *g*) first ppears, the cones continuing rather further than the rods, but soon ng; the nerve- and ganglionic layers, which were already very thin incomplete, cease altogether at the ora, the inner molecular layer (*c*), h is now largely occupied by Müllerian fibres, retains its thickness o a certain point, and then abruptly terminates (*a'*), while the nuclear rs, outer and inner, (*f*, *d*), here become merged into a single stratum, h appears to be continuous with the columnar cells of the pars ris. These cells (fig. 356, *m*), which are at first of considerable

Fig. 356.

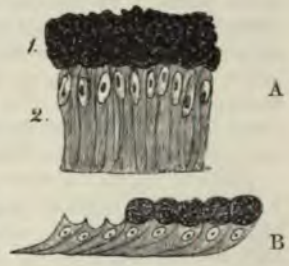


356.—VERTICAL SECTION THROUGH THE CHOROID AND RETINA NEAR THE ORA SERRATA (Kölliker). 60 DIAMETERS.

hyaloid membrane; *b*, ing membrane and ner- layer of the retina; *c*, lionic and inner molecular with closely set Mülle- fibres; *d*, inner nuclear; ter molecular; *f*, outer ear layer; *g*, columnar ; *h*, pigment; *i*, *k*, cho- ; *l*, part of one of the y processes; *m*, pars cili- of the retina. (The recess n at *a''* is not constant.)

gth, become gradually shorter anteriorly; they are finely striated . 357, 2), and each cell has a clear oval nucleus at the outer part of cell, near the pigmentary layer. The inner end may be rounded,

Fig. 357.



357.—A SMALL PORTION OF THE CILIARY PART OF THE RETINA (Kölliker). 350 DIAMETERS.

A, human; B, from the ox; 1, pigment-cells; cells forming the pars ciliaris.

inted, square, or even branched; the les of the cells, too, are sometimes even.

These cells are considered by Kölliker correspond with the Müllerian fibres the retina, but according to Schwalbe e Müllerian fibres, or rather their ited inner ends, are represented by delicate membrane, which covers the inner ends of the columnar cells d sends fine offsets around and between them.

Vessels of the Retina.—A single artery (*arteria centralis retinæ*) sses between the bundles of fibres of the optic nerve to the inner rface of the retina at the middle of the papilla optici (fig. 345, *a*). It accompanied by the corresponding vein and soon divides into branches g. 344), usually two, one above, the other below, each of these again iding into two branches which arch out towards the sides; the outer s are somewhat the larger, and as they bend round the macula lutea y send numerous fine branches into it which end at the margin of the

Hesse), so that the outer retinal layers are entirely destitute vessels.

The vascular system of the retina is nowhere in direct communicat choroidal vessels. Near the entrance of the optic nerve, however, i communication with some offsets from the sclerotic coat, and the cho also send branches to join the long-meshed network in the optic ner by the central artery. The arteries of the retina have the usual c veins resemble capillaries in structure, their walls consisting of a si epithelial cells without any muscular tissue. Outside the epitheli space (perivascular lymphatic, His) both in the veins and capillar externally by a second epithelial layer (forming the wall of the lymp side this again is found, in the case of the veins, a layer composed retiform tissue. These perivascular lymphatics are in communicat lymphatics of the optic nerve, and may be filled by injecting c under the sheath which that nerve derives from the pia mater. spaces also become injected by the same process, viz., the interstices nerve-bundles which radiate from the papilla optici, the capillary s the limitans interna and the hyaloid membrane of the vitreous finally even the irregular interstice between the pigmentary layer a of rods and cones (Schwalbe).

THE VITREOUS BODY.

The vitreous body occupies the greater portion of the eye quite pellucid in aspect, and of a soft gelatinous consiste globular in form, it fills about four-fifths of the ball, and support for the delicate retina, but it may be readily separat latter, except behind, at the entrance of the optic nerve, connection is closer, the retinal vessels having here en fœtal life. At the fore part it is hollowed out for the recep lens and its capsule, to which its substance is closely adheren

The surface of the vitreous humour is covered everywher front by a thin glassy membrane, named *hyaloid*, which li it and the retina. No vessels enter the vitreous humour in and its nutrition must, therefore, be dependent on the s vascular structures, viz., the retina and the ciliary processes.

Although in the fresh state apparently structureless, or at leas

s of such membranous partitions has not been conclusively demonstrated. wever, the vitreous substance does in some way consist of a firmer —whether or not in the shape of continuous membranes—enclosing in s the more fluid portion, is shown by the fact that if either the whole or f the vitreous humour be thrown upon a filter, a small proportion always upon the latter; although by far the larger part drains away, and may ted as a clear watery fluid.

Fig. 358.

.—HORIZONTAL SECTION OF THE 'S EYE, HARDENED IN CHROMIC fter Hannover).

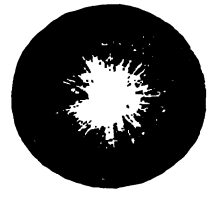
itreous humour appears concen- ed meridionally striated through- hole depth.

dition to the above-mentioned ric striation, a radial marking been observed in sections eous humour made trans- to the axis of the eyeball), but whether there is any ent structure to account for earance is not known. It is ible that these appearances merely produced by the manner in which the albuminous substance has me coagulation by the reagent employed.

ever this may be, there exists, nearly but not quite in the axis of , a definite structure in the shape of a distinct canal, about a twelfth nch in diameter, filled with fluid and extending from the *papilla* o the back of the lens-capsule, where it apparently terminates . This is the *canalis hyaloideus* or *canal of Stilling*. It is best in the fresh eye, and may be also injected by forcing a coloured n under the pia-matral sheath of the optic nerve (Schwalbe). nal widens somewhat towards its posterior part: its wall is ed of an extremely delicate homogeneous membrane. It repre- he place of passage of an offset from the central artery of the to the capsule of the lens in the fœtus.

Fig. 359.

.—TRANSVERSE SECTION OF HUMAN EYE, HARDENED ROMIC ACID, SHOWING RADIAL STRIATION OF THE OUS BODY (after Hannover).



tered about throughout the substance of treous humour are a variable number of cles, for the most part possessed of amœboid ent. Some of these cells are remarkable for ry large vacuoles which they contain, and distend the body of the corpuscle, pushing cleus to one side; the cell-processes are often peculiar in possessing nus little secondary bud-like swellings, or they may present a e appearance, like strings of pearls.

hyaloid membrane invests, as before mentioned, the whole of reous humour, except in front, where the membrane passes ls to the anterior part of the margin of the lens, becoming also in consistence and distinctly fibrous in structure. This portion hyaloid is known as the *zonula of Zinn*, or *zonula ciliaris*. It is

also known as the *suspensory ligament of the lens* (fig. 36(posterior part, or hyaloid proper, is exceedingly thin and deli readily thrown into folds when detached. Under the mi presents no appearance of structure: but, flattened again surface are generally to be seen a number of granula corpuscles, which exhibit amœboid movements: they ap migrated white blood corpuscles. The ciliary part or c zonula, on the other hand, presents radiating meridional fil appearance but possessed of considerable elasticity; they comi opposite the ora serrata, and strengthen this portion of membrane. From the ciliary processes the zonula is con distinct membrane to the front of the lens, to the capsu it is anteriorly firmly attached. But in addition to t membranous prolongation of the hyaloid membrane, o fibres, more scattered in their disposition, pass across to th of the lens, some being attached to the extreme edge, oth into continuity with the posterior capsule, and others agai intermediate positions (fig. 360, *P*). The interstices of thes *fibres of the lens* are occupied during life by fluid, or perhap

Fig. 360.

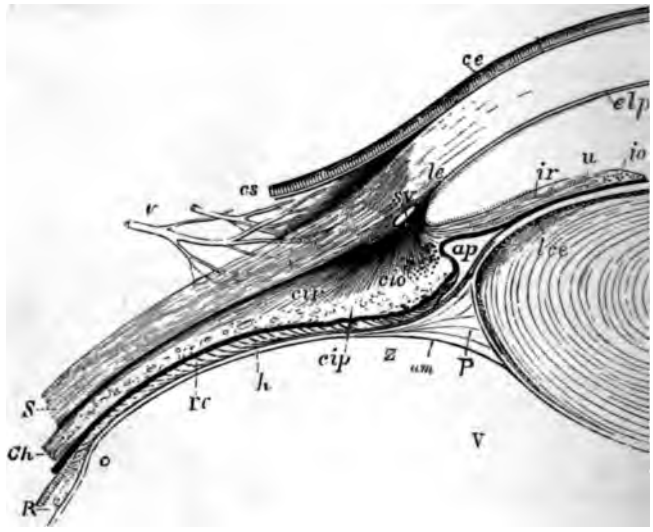


Fig. 360.—SECTIONAL VIEW OF THE CONNECTIONS OF THE CORNEA, S CILIARY MUSCLE, CILIARY PROCESSES, HYALOID MEMBRANE AND LENS (Alle

The specimen extends from the middle of the lens to the ora serrata o of the right eye. *C*, cornea; *cs*, conjunctiva; *ce*, epithelium of the co terior elastic layer; below *le*, ligamentum pectinatum iridis; *S*, sclerotic; chamber; *ap*, the recess forming the posterior division of the aqueous canal of Schlemm; *ir*, iris; *io*, divided fibres of the sphincter muscle; u or uvea; *ln*, centre of the crystalline lens; *lc*, capsule of the lens; *lce* the lens; *cir*, radiating ciliary muscle; *cio*, divided annular fibres; *cip*, *Ch*, choroid; *R*, retina; *o*, ora serrata; *rc*, the ciliary part of the ret membrane; *Z*, zonule of Zinn; *P*, some of its fibres spreading out to l to the capsule of the lens; *am*, anterior margin of the vitreous humour,

us humour; but after death they may be distended with air: if ne after removal of the anterior parts which support and enclose ds of the suspensory ligament, which correspond with the emi- d depressions of the ciliary processes, are distended, and the ap- of a sacculated canal (*canal of Petit*), encircling the lens, is as in fig. 361.

ing to the account usually given, the hyaloid membrane divides nto two layers; an anterior, continued forwards as the zonule and a posterior, passing behind the lens; the canal of Petit tained between them. The above description is based upon a riginal investigation into the relations of the structures which he lens, and is confirmatory of the statements of Merkel, Henle, nd others, and opposed to those of Iwanoff.

Fig. 361.

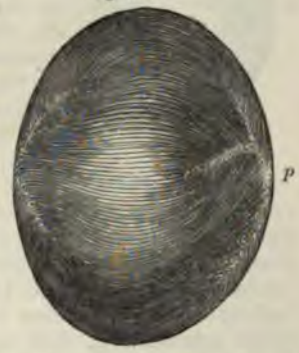
VIEW FROM BEFORE OF THE CANAL OF PETIT INFLATED (from Sappey).

rior parts of the sclerotic, choroid, iris and cornea n removed, the remaining parts are viewed from l the canal of Petit has been inflated with air artificial opening. 1, front of the lens; 2, dy; 3, outer border of the canal of Petit; 4, outer e zonule of Zinn; 5, appearance of sacculated of the canal of Petit.

THE LENS.

ens (*lens crystallina*) is a transparent solid body, of a doubly shape, with the circumference rounded off. It is completely by a transparent elastic membrane known as the *capsule of* The anterior surface is in contact with the iris towards the ceding from it slightly at the circumference; the posterior is

Fig. 362.



–THE LENS VIEWED FROM ITS LATERAL ASPECT (after Arnold.) ⅔

ior; *p*, posterior pole. The direction perficial fibres is indicated by the s.

d in the vitreous humour. the circumference is the zonula. exity is not alike on the two being greater behind; more- curvature is less at the centre wards the margin. When in ral position it measures about an inch across, and ⅓th from backwards. In a fresh lens, of its capsule, the outer portion nd easily detached; the succeeding layers are of a firmer ce; and in the centre the substance becomes much harder, ing the so-called "nucleus." On the anterior and posterior are faint white lines directed from the poles towards the cir- ce; these in the adult are somewhat variable and numerous on ces (fig. 363), but in the fœtal lens throughout, and towards re of the lens in the adult, they are three in number, diverging h other like rays at equal angles of 120° (fig. 364). The

lines at opposite poles have an alternating position (not b one another), thus of those seen on the posterior surface of

Fig. 363.

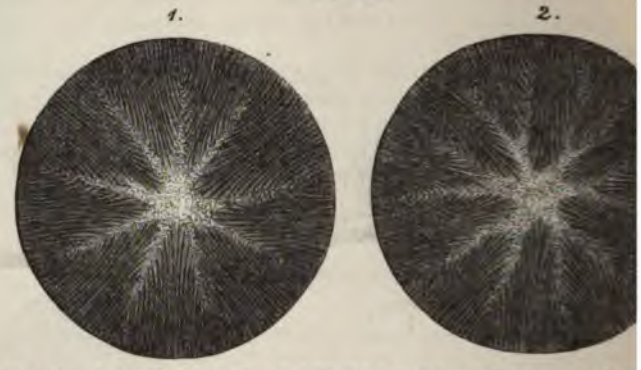


Fig. 363.—1, FRONT VIEW; 2, HIND VIEW OF THE FIBROUS STRUCTURE O LENS (after Arnold). $\frac{6}{1}$

lens, one is directed vertically upwards, and the other t wards and to either side, whereas those on the anterior s

Fig. 364.

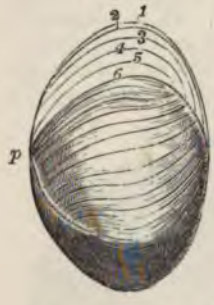


Fig. 364.—DIAGRAM TO ILLUSTRATE THE COU FIBRES IN THE FŒTAL CRYSTALLINE LENS (Aller

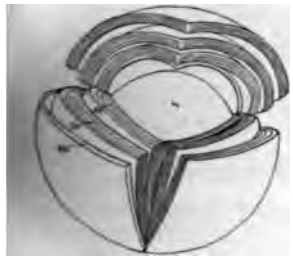
a, anterior; *p*, posterior pole.

directed one directly downwards and two upwards and to the sides. These the edges of planes or septa within diverging from the axis, and receiving of the lens-fibres, which here abut a another. As Tweedy has pointed out, be seen, by the aid of the ophthalmosc during life. The rays seldom meet a but usually along a somewhat irregula area.

Structure.—When the lens has been hardened and th removed, a succession of concentric laminæ may be detache like the coats from an onion. They are not continuous, bu into parts opposite the radiating lines above described (fig. 3 laminæ are composed of long, riband-shaped, microscopic fi inch broad, which adhere together by their edges, the latter b finely serrated (fig. 366, A), and pass in a curved direction intersecting planes of the anterior half of the lens to th posterior half, or *vice versâ*: in this course no fibre passes pole to the other, but those fibres which begin near the pole of one surface, terminate near the marginal part of a pla opposite surface, and conversely; the intervening fibres passi corresponding places between. The arrangement will be bet stood by a reference to fig. 364, where the course of the fib fœtal lens is diagrammatically indicated.

lens-fibres, as the history of their development shows, are to be upon as much elongated cells. In the young state each has oval nucleus, but in the fully-formed lens the nuclei have dis-

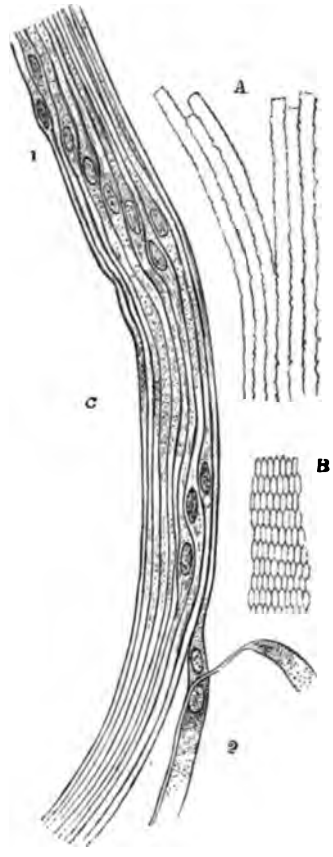
Fig. 365.



365. — LAMINATED STRUCTURE OF THE FALLINE LENS, SHOWN AFTER HARDENING COHOL (Arnold). ‡

ucleus; 2, 2, lamellæ.

Fig. 366.



366.—FIBRES OF THE CRYSTALLINE LENS. 350 DIAMETERS.

ngitudinal view of the fibres of the lens he ox, showing the serrated edges. B, nse section of the fibres of the lens from man eye (from Kölliker). C, longitudinal of a few of the fibres from the equatorial of the human lens (from Henle). Most fibres in C are seen edgeways, and, towards nent the swellings and nuclei of the lear zone;" at 2, the flattened sides of bres are seen.

ared from the fibres which form more internal parts of the lens, and remain in the most superficial rs. Here they are found, not quite he middle of each fibre, but slightly rer the anterior end, their situation ly corresponding in adjacent fibres, they form by their juxtaposition the so-called "nuclear zone" around lens. The superficial fibres further differ from the more deeply seated s in being softer, and in possessing a plain, unserrated margin. e extremities of all the fibres are softer and more readily acted on by gents than the middle parts, and the axial or more internal part of a e more so than the external, but the transition is gradual from one to other, and there is no definite membrane enclosing each fibre. The -fibres when cut across are seen to be six-sided prisms (fig. 366 B). reason of this shape, and the serrations of their edges, they fit very tly the one to the other with but little interfibrillar cementing tance between. This is met with in rather larger quantity in the secting planes between the ends of the fibres.

in and Ewart have shown that with certain methods of treatment the

superficial lens-fibres show indications of being composed of a number
segments separated by sharply marked lines of inter-segmental substan

Epithelium of the capsule.—At the back of the lens the f
directly in contact with the inner surface of the capsule, but in fr
are separated from the latter by a single layer of flattened, po
nucleated cells, which covers the whole anterior surface unders
capsule. Towards the edge or equator of the lens the appearan
character of these cells undergo a change : they first gradually t
columnar form, and then, becoming more and more elongated,
every transition to the nucleated lens-fibres of the superficial lay
which they are directly continuous. This transition is more easil
in the lens of some animals than in man (see fig. 367).

Fig. 367.

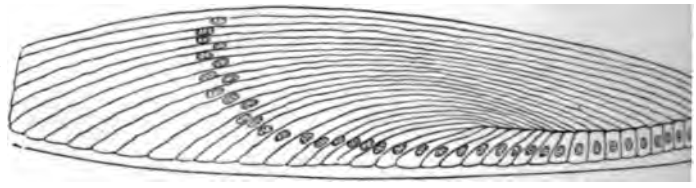


Fig. 367.—SECTION THROUGH THE MARGIN OF THE RABBIT'S LENS, SHOWI
TRANSITION OF THE EPITHELIUM INTO THE LENS-FIBRES (Babuchin).

The capsule of the lens is a transparent, structureless membrane, as
brittle and elastic in character, and when ruptured the edges roll outwards.
part of the capsule, from about $\frac{1}{12}$ inch from the circumference, where the
part of the suspensory ligament joins it, is much thicker than the back:
posterior pole of the lens the capsule is very thin indeed. In the adult
the lens itself, is entirely non-vascular, but in the fœtus there is a netw
vessels in the capsule, supplied by the terminal branch of the central
of the retina, which passes from the optic papilla through the canal of
in the vitreous humour to reach the back of the capsule, where it
into radiating branches. After forming a fine network, these turn rou
margin of the lens and extend forwards to become continuous with the vas
the pupillary membrane and iris.

After death a small quantity of fluid (liquor Morgagni) frequently
between the back of the lens and the capsule : it appears to be derived fr
lens-fibres. There is no epithelium in this situation as in front.

Changes in the lens with age.—In the *fœtus*, the lens is nearly sp
(fig. 368, *a*) : it has a slightly reddish colour, is not perfectly transparent,
softer, and more readily broken down than at a more advanced age.

Fig. 368.

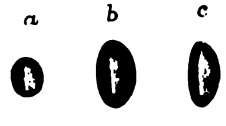


Fig. 368.—SIDE VIEW OF THE LENS AT DIFFERE

a, at birth with the deepest convexity ; *b*, in a
with medium convexity ; *c*, in old age with con
flattening of the curvatures.

In the *adult*, the anterior surface of the lens is distinctly less conv
the posterior (fig. 368, *b*) ; and the substance of the lens is firmer, co
and transparent.

In *old age*, it is more flattened on both surfaces (*c*) ; it assumes a yell
amber tinge, and is apt to lose its transparency as it gradually incr
toughness and specific gravity.

AQUEOUS HUMOUR AND ITS CHAMBER.

The aqueous humour fills the space in the fore part of the eyeball, between the capsule of the lens with its suspensory ligament and the cornea. The iris, resting in part upon the lens, divides the aqueous chamber partially into two, named respectively the anterior and posterior chambers. This subdivision is incomplete in the adult, but in the fœtus before the seventh month it is completed by the membrana pupillaris, which by its union with the margin of the pupil, closes the aperture of communication between the two chambers.

The *anterior chamber* is limited in front by the cornea and behind by the iris, while opposite the pupil it is bounded by the front of the lens and its capsule.

The *posterior chamber* was originally so named in the belief that a distinct free space intervened between the iris and the capsule of the lens. It is now, however, well ascertained by observations on the living eye, and by sections made in the frozen state, that the iris comes into contact with the capsule of the lens, both at the pupillary margin and at the adjoining part of the posterior surface; and the term posterior chamber should therefore only be applied to the angular interval existing at the circumference between the ciliary processes, the iris, and the zonula (fig. 4, *ap.*)

Recent Literature of the Eye.—On the macroscopic anatomy of the eye:—*F. Arlt*, Article in Graefe & Saemisch' Handbuch d. gesammt. Augenheilkunde, I. Bd., 1874; *Heinlein*, in Arch. f. Ophthalm., XXI., 1875 (lachrymal canals); *Löwe*, in Arch. f. mikr. Anat., XV., 1878; *J. Gerlach*, Beiträge, &c., Leipzig, 1880; *Angelucci*, Arch. f. mikr. Anat., XIX., 1880 (structure and devel. of anterior part of bulb).

On the eyelid and conjunctiva:—*Waldeyer*, in Graefe & Saemisch' Handb., 1874; *Longhi*, in Arch. f. mikr. Anat., XI. (nerves); *Ciaccio*, in Mem. d. accad. di Bologna, IV., and in Moleschott's Unters., XI., 1874; *Reich*, in Arch. f. Ophthalm., XXII., 1875; *Poncet et Cadiat*, in J. d. l'anat., 1875 (lachrymal ducts); *Waltzberg*, "Bau der Thränenorgane," &c., Rostock, 1876; *Sattler*, in Arch. f. mikr. Anat., 1877; *Tartuferi*, in Giorn. Accad. d. sci. med., 1879 (epithelium of eyelid), and in Archiv. d. sci. med., IV., 1879 (glands of eyelid); *Baumgarten*, in Arch. f. Ophth., XXVI., 1880.

On the cornea and sclerotic:—*Waldeyer*, in Graefe & Saemisch' Handbuch, 1874; *Schlagfer*, in Virchow's Arch., LXIII., 1875; *Ciaccio*, in Mem. d. accad. di Bologna, 1875; *Meyerowitz*, "Mikr. Untersuch." &c., Leipzig, 1875; *Eberth*, in Zürich Untersuch. 3, 1875; *Swaen*, in Bull. de l'acad. de Belgique, 1876; *Raelmann*, in Arch. f. Ophth., XXIII., 1877; *Leber*, in Arch. f. Ophth., 1878 (intercellular spaces in epith.); *Berling and Skinner*, in the J. of Physiol., I., 1878; *Heisrath*, in Arch. f. Ophth., XXVI. (communication of anterior chamber with canal of Schlemm).

On the choroid coat and iris:—*Iwanoff*, in Graefe and Saemisch' Handb., 1874; *Schöler*, Structur d. Iris-stroma, Erlangen, 1875; *Faber*, Bau d. Iris, Leipzig, 1876; *Müller*, in Arch. f. Ophthalm., XXII., 1876; *J. Gerlach*, in Erlangen Sitzungsb., 1879; *Meyer*, in Arch. f. mikr. Anat., XXII., 1879 (nerves of iris).

On the retina:—*M. Schultze*, Article in Stricker's Handbook, 1871; *Schwalbe*, in Graefe and Saemisch' Handb., 1874; *Michel*, in Beiträge, &c., als Festgabe an C. Ludwig, 1875 (arrangement of fibres in nerve-fibre layer); *W. Müller*, in the same work (morphological); *Merkel*, in Arch. f. Ophthalm., XXII., 1876; *W. Krause*, Die Nervenendigung in der Retina, in Arch. f. mikr. Anat., XII., 1876; *Boll*, in Monatsbericht d. Berlin Akad., 1876, 1877; and in Arch. f. (Anat. u.) Phys., 1877; *Kühne*, in Med. Centralbl., 1877 & 1878; and in Heidelb. Unters., I., 1877, and II., 1878; and with *Sewald* in the same; *Kuhnt*, in Monatsbl. f. Augenheilk., 1877, and in Med. Centralb., 1877 (pigment epithelium); *Gunn*, in J. of Anat. and Phys., 1877; *Angelucci*, in Arch. f. (Anat. u.) Phys., 1878 (retinal pigment); *Dennisenko*, in Arch. f. mikr. Anat., 1880; *Retzius*, Biol. Unters., Stockholm, 1881.

On *the lens and vitreous humour*:—*Arnold*, in Graefe and Saemisch' Handb.; *Schwalbe* (vitreous) in the same, 1874; *Hosch*, in Arch. f. Ophthalm., XX., 1874; *Iwanoff and Ewart*, in the Journ. of Anat., 1876; *Ritter*, in Arch. f. Ophth., XXIII., 1877;

Henle, Göttinger Abhandl., XXIII., 1879; *Brailey*, in Guy's Hosp. Reports, XII (suspensory apparatus of lens); *Ulrich* (canal of Petit), in Arch. f. Ophthalm.,

On the blood-vessels and lymphatics of the eye.—*Leber*, in Graefe misch' Handb., 1874. Of the eyelids: *Fuchs*, in Arch. f. Ophth., 1878, Centralbl., 1878; and *Langer*, in Med. Jährb., 1878. Of the retina: Ophth. Hosp. Reports, 1875; *Hesse*; *His*, in Arch. f. Anat. (u. Phys.), 1880; in Arch. f. Ophth., 1881.*

THE EAR.

THE organ of hearing is divisible into three parts: the exte (fig. 369, 1, 2), the tympanum or middle ear (3), and the labyr internal ear (6). The first two of these are to be consid accessories to the third, which is the sentient portion of the organ

Fig. 369.

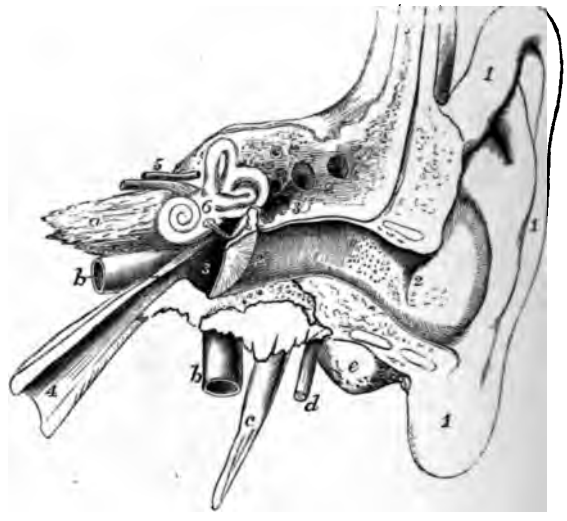


Fig. 369.—DIAGRAMMATIC VIEW FROM BEFORE OF THE PARTS COMPOSING THE OF HEARING OF THE LEFT SIDE (after Arnold).

The temporal bone of the left side, with the accompanying soft parts, has been from the head, and a section has been carried obliquely through it so as to the front of the meatus externus, half the tympanic membrane, and the upper and wall of the tympanum and Eustachian tube. The meatus internus has also been and the bony labyrinth exposed by the removal of the surrounding parts of the bone. 1, the pinna and lobe; 2 to 2', meatus externus; 2', membrana tym cavity of the tympanum; above 3, the chain of small bones; 3', opening into the cells; 4, Eustachian tube; 5, meatus internus, containing the facial (upper auditory nerves; 6, placed on the vestibule of the labyrinth above the fenestra apex of the petrous bone; *b*, internal carotid artery; *c*, styloid process; *d*, issuing from the stylo-mastoid foramen; *e*, mastoid process; *f*, squamous part of

THE EXTERNAL EAR.

In the external ear are included the *pinna*—the part of the ou which projects from the side of the head—and the *meatus* or passag leads thence to the tympanum, and which is closed at its inner en by a membrane interposed between it and the middle ear.

* The older literature of the eye will be found in the several articles referred Handbuch der gesammten Augenheilkunde, 1874.

THE PINNA.

general form of the pinna or auricle, as seen from the outside, is **, to** fit it for collecting and concentrating the undulations of **but** it is thrown into various elevations and hollows, to which **; names** have been given. The largest and deepest concavity is **he** *concha* (fig. 370, 7); it surrounds the entrance to the meatus, **interrupted** at its upper and anterior part by a ridge, which is the **ing** of the helix. In front of the concha, and projecting back- **over** the meatus, is a conical prominence, the *tragus* (fig. 370, 6), **l usually** with hairs. Behind this, and separated from it by a

Fig. 370.

—OUTER SURFACE OF THE PINNA OF THE RIGHT AURICLE. ⅔

ix; 2, fossa of the helix; 3, antihelix; 4, fossa ntihelix; 5, antitragus; 6, tragus; 7, concha; a.

notch, is another smaller elevation, the *gus* (5). Beneath the antitragus, and g the lower end of the auricle, is the (8), which is devoid of the firmness lasticity that characterise the rest of the . The thinner and larger portion of the is bounded by a prominent and incurved in, the *helix* (1), which, springing above ather within the tragus, from the hollow ie concha, surrounds the upper and ior margin of the auricle, and gradually itself in the back part of the lobule. in the helix is another curved ridge, the *antihelix* (3), which, ning below at the antitragus, sweeps round the hollow of the a, forming the posterior boundary of that concavity, diverging it into two ridges. Between the helix and the antihelix is a narrow d groove, the *fossa of the helix* (fossa scaphoidea) (2); and in the f the antihelix is a somewhat triangular depression, the *fossa of the elix* (fossa triangularis) (4).

light pointed projection which is occasionally observed in the human t at the margin of the helix (at a place indicated by the asterisk in fig. s of interest as representing the much more distinct pointed extremity met in the expanded ears of quadrupeds (Darwin, "The Descent of Man," 2nd n, p. 15). The point in question is distinctly seen in the cartilage repre- d in fig. 371.

ructure.—The pinna consists mainly of yellow fibro-cartilage and ument, with a certain amount of adipose tissue. It has several ents and small muscles of minor importance.

e *skin* covering it is thin, closely adherent to the cartilage, and ins sebaceous follicles, which are most abundant in the hollows of oncha and scaphoid fossa.

e *cartilage* (fig. 371, A, B) forms a thin plate, presenting all the alities already described as apparent on the outer surface of the , and on its cranial surface having prominences the reverse of the a and the fossa of the helix, while between these is a depression in

the situation of the antihelix. The cartilage is not confined
pinna, but enters likewise into the construction of the outer pa
external auditory canal. When dissected from other structure
seen to be attached by fibrous tissue to the rough and prominent
of the external auditory meatus of the temporal bone. The tub
is cleft in front between the tragus and fore part of the helix in
the bone, the deficiency being filled with fibrous membrane; the
cartilage may be looked upon as an elongated plate, the lower
which is folded round in front so as to bring it nearly into contact
the upper part. There is no cartilage in the lobule: it contains
and tough connective tissue.

Behind the prominence of cartilage which forms the antitragus is a
notch, separating it from the cartilage of the helix, which here forms a
process descending towards the lobule. At the fore part of the pinna,
the first bend of the helix, is a small conical projection of the cartilage,
the *process of the helix*, to which the anterior ligament is attached. Behind
process is a short vertical slit in the helix; and on the surface of the tra
a similar but somewhat longer fissure. A deep fissure passes back betwe
commencement of the helix and the tube of the ear, and another passing
wards and backwards from the deep end of the longitudinal cleft separat
part forming the tragus from the rest of the tube, so that the tube is conn
with the pinna only by means of a narrow isthmus. One or two other irr
gaps or fissures partially divide the cartilaginous tube transversely, and the
of these deficiencies are termed *fissures of Santorini*. The substance of the c
lage is very pliable, and is covered by a firm fibrous perichondrium.

Of the *ligaments of the pinna*, the most important are two, which ser
attaching it to the side of the head. The *anterior* ligament, broad and thi
extends from the process of the helix to the root of the zygoma. The *post*
ligament fixes the back of the auricle (opposite the concha) to the outer sur
of the mastoid process of the temporal bone. A few fibres attach the tragus
to the root of the zygoma. Ligamentous fibres are likewise placed acros
fissures and intervals left in the cartilage.

Of the *muscles of the pinna*, those which are attached by one end to the sid
the head, and move the pinna as a whole, have been already described (vol. I
there remain to be examined several smaller muscles, composed of thin layers
pale-looking fibres, which extend from one part of the pinna to another, a
may be named the special muscles of the organ. Six such small muscles
distinguished; four being placed on the outer and two on the inner or d
surface of the pinna.

The *smaller muscle of the helix* (fig. 371, 1) is a small bundle of oblique fib
lying over, and firmly attached to, that portion of the helix which springs fro
the bottom of the concha.

The *greater muscle of the helix* (2) lies vertically along the anterior margin of
the pinna. By its lower end it is attached to the process of the helix; and
above, its fibres terminate opposite the point at which the ridge of the helix
turns backwards.

The *muscle of the tragus* (3) is a flat bundle of short fibres covering the outer
surface of the tragus: its direction is nearly vertical. Occasionally a slender
bundle of muscular fibres is seen prolonging this muscle across the cleft in the
cartilage between the tragus and fore part of the helix.

The *muscle of the antitragus* (4) is placed obliquely over the antitragus and
behind the lower part of the antihelix. It is fixed at one end to the antitragus,
from which point its fibres ascend to be inserted into the tail-like extremity of
the helix, above and behind the lobule.

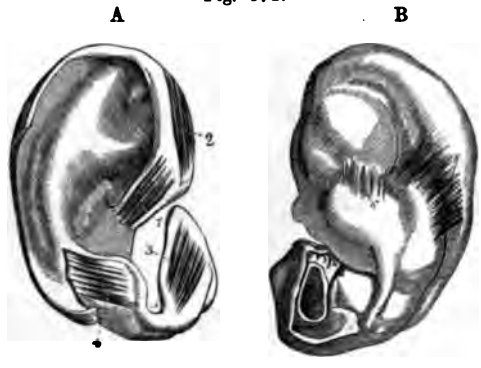
The *transverse muscle* (5) lies on the inner or cranial surface of the pinna, and
consists of radiating fibres which extend from the back of the concha to the
prominence which corresponds with the groove of the helix.

The *oblique muscle* (Tod) (6) consists of a few fibres stretching from the back

to the convexity directly above it, across the back of the inferior antihelix, and near the fibres of the transverse muscle.

l nerves of the pinna.—The auricular branch of the *posterior ry*, a branch from the external carotid, is distributed chiefly on the out sends small branches round and through the cartilage to ramify urface of the pinna. Besides this artery, the auricle receives the *ular* from the superficial temporal.

Fig. 371.



d B.—OUTER SURFACES OF INNA, EXPOSED E SMALL MUS- ARNOLD).

helicis minor; ajor; 3, tra- gicus; 5, mus- us auriculæ; iquus auriculæ.

or the most y the arteries. posterior auri- mporal veins. *auricular* the cervical es the greater nner surface of the auricle, and sends small filaments with the cular artery to the outer surface of the lobule and the part of the The auricular branch of the *posterior auricular nerve*, derived from ter communicating with the *auricular branch of the pneumogastric*, e back of the ear and supplies the retrahent muscle. The anterior uscles of the auricle receive their supply from the *temporal branches* nerve. The *auriculo-temporal* branch of the third division of the ves filaments chiefly to the outer surface of the pinna. A branch *ccipital* supplies the upper part of the inner surface.

THE EXTERNAL AUDITORY CANAL.

nal auditory canal, *meatus auditorius externus* (369, 2, 2), m the bottom of the concha to the membrane of the and serves to convey the vibrations of sound to the middle the ear. The canal is about 1¼ inches long. In its inward inclined somewhat forwards (fig. 372); and it has likewise a ical curve (fig. 369), being at first directed somewhat up- afterwards turning over a convexity in the floor of the to dip downwards to its termination. The calibre of the mallest about the middle. The outer opening is largest from wards, but the inner end of the tube is slightly wider in the irection. At the inner extremity the tube is terminated by na tympani, which is placed obliquely, being inclined down- ards, and towards the mesial plane; and thus, as shown in floor of the meatus is longer than its roof.

us is composed partly of cartilage, and partly of bone, and is rolongation of the skin.

laginous part occupies somewhat less than half the length of . It is formed, as already mentioned, by an inflection of the f the cartilage of the pinna.

us portion is a little longer and rather narrower than the car-

tilaginous part. At its inner end is a narrow groove, which
round the sides and floor of the meatus, but is deficient above; in
the margin of the membrana tympani is inserted.

The skin of the meatus is continuous with that covering the
but is very thin, especially in the osseous part, and becomes gra
thinner towards the bottom of the passage. In the osseous

Fig. 372.

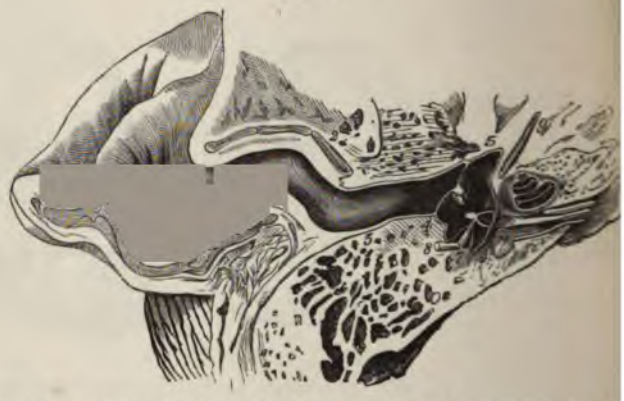


Fig. 372.—VIEW OF THE LOWER HALF OF THE AURICLE AND MEATUS IN THE
DIVIDED BY A NEARLY HORIZONTAL SECTION (after Rüdinger).

1. Posterior wall; 2, anterior wall of the cartilaginous meatus; 3, posteri
the bony meatus; 4 to 5, membrane of the tympanum, with the handle of the
cut; 6, stapes, to the right of 6, section of the cochlea; 7, stapedius mu
section of facial nerve; 10, branches of the auditory nerve to the cochlea, sac
utricle, 11.

adheres very closely to the periosteum, and at the bottom of the
stretched over the surface of the membrana tympani, forming th
layer of that structure. Towards the outer part the skin posses
hairs and sebaceous glands; and in the thick subdermic tissue o
cartilage are many small oval glands of a brownish yellow colour, ag
in form and structure with the sweat glands, but larger (fig. 1
p. 254). The cerumen or ear-wax is secreted by these glands (*gl
ceruminosæ*), and their numerous openings may be seen to perfor
skin of the meatus. Hairs and glands are absent from the bony
the tube.

Vessels and nerves.— The external auditory meatus is supplied with
from the *posterior auricular*, *internal maxillary*, and *temporal* arteries; a
nerves chiefly from the auriculo-temporal branch of the fifth nerve. Th
cipal branches of the arteries course along the upper and back wall of the

State in the infant.—The auditory passage is very short and rudim
in the infant, for the osseous part begins to grow out of the temporal bo
after birth, and thus the internal and middle parts of the ear are much c
the surface than in the adult (vol. i. p. 71).

THE MIDDLE EAR OR TYMPANUM.

The tympanum or drum, the middle chamber of the ear, is a
irregular cavity in the substance of the temporal bone, placed b
the membrane occluding the inner end of the external auditor

outer bony wall of the labyrinth. Its width between these s varies from about $\frac{1}{12}$th to $\frac{1}{6}$th of an inch. It contains a chain bones, by means of which the vibrations communicated from o the membrana tympani are conveyed across the cavity to the ear, and also certain minute muscles and ligaments, which the bones referred to, as well as nerves, some of which end e cavity, whilst others merely pass through it to other parts. y is otherwise filled with air, for it communicates with the at- through the Eustachian tube, which leads into the pharynx. id floor, an outer and inner wall, and an anterior and posterior are commonly described.

of of the tympanum is formed by a thin plate of bone, which asily broken through so as to obtain a view of the tympanic m above ; it is situated on the upper anterior surface of the ortion of the temporal bone, near the angle of union with the portion. The *floor* is narrow, in consequence of the outer and ndaries being inclined towards each other. It is separated by te of bone from the jugular fossa behind and the carotid canal

ter wall is formed, to a small extent, by bone, but mainly by the e (*membrana tympani*) already mentioned as closing the inner e external auditory meatus. Immediately in front of the ring into which the membrana tympani is inserted, is the inner ex- f the fissure of Glaser. Close to the back of this fissure is the of a small canal, through which the chorda tympani nerve it from the tympanum.

membrana tympani is an ellipsoidal disc, the longer axis of directed from behind and above, forwards and downwards, and

Fig. 373.

—VIEW OF THE OUTER SURFACE LEFT MEMBRANA TYMPANI, AFTER L OF THE CUTANEOUS LAYER). ‡

dle of the malleus is distinctly . the long process of the incus a faint light band parallel with e behind the handle of the mal- e other light band nearly at right the malleus is caused by the mpani nerve. The notch of Ri- m above the handle of the mal- termination of the posterior wall ernal auditory meatus.

0.37 inches (9.25 mm.) in the shorter axis being about hes (8.25 mm.). It is inserted into the groove already noticed nd of the meatus externus, and so obliquely that the membrane towards the anterior and lower part of the canal at an angle of 5°. The handle of the malleus (fig. 373), one of the small bones tympanum, descends in contact with the inner surface of the ne, covered by mucous membrane, to a little below the centre, ; is firmly fixed ; and, as this process of the bone is directed . the outer surface of the membrane is thereby depressed in a form.

membrana tympani is about $\frac{1}{100}$ inch (0.1 mm.) thick. Covering it

externally is a prolongation of the skin of the external meatus; inte
is a prolongation of the mucous membrane lining the cavity of the
panum; and between these two is the proper substance of the mem
composed of fibrous tissue. The greater number of the fibres radiate
the attachment of the handle of the malleus (fig. 373), but there ar
circular fibres which are situated within or mesially to the radial
closer to the circumference, form a dense, almost ligamentous ring.
radial fibres are not straight, but are slightly bowed outwards, so
between the most depressed point or *umbo*, and the attached borde
membrane is slightly convex outwardly. This shape is maintain
the annular fibres.

At the upper and anterior part, the annular fibres stretch acro
mouth of a small notch in the bony ring to which the membrane is att
(notch of Rivini). The notch is occupied by a lax part of the mem
(*membrana flaccida*, Shrapnell), consisting of loose connective tissue,
vessels and nerves, and covered by skin and mucous membrane. It
sionally happens that a fissure or perforation is to be detected at this

Fig. 374.

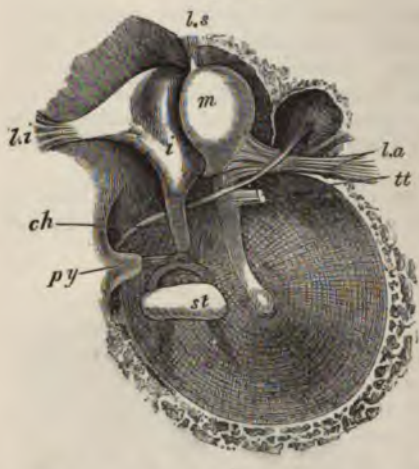


Fig. 374.—VIEW OF THE LEF
BRANA TYMPANI AND AUDITO
SICLES FROM THE INNER SIDE
SOMEWHAT FROM ABOVE (E.A.S

m, malleus; *i*, incus; *st*,
py, pyramid from which the
of the stapedius muscle is
emerging; *t t*, tendon of the
tympani cut short near its inse
l a, anterior ligament of the ma
the processus gracilis is conti
the lower fibres of this ligament
superior ligament of the malleus
ligament of the incus; *ch*,
tympani nerve passing across the
wall of the tympanum.

The membrane is supplied
blood-vessels, but they are ch
confined to the skin and mu
membrane covering the surfa
a few are, however, found in
proper fibrous membrane.
form a communication betw
the two systems on the surfaces. Those of the skin are mostly supplied
small artery, derived from the deep auricular branch of the internal maxill
which passes from above, parallel to and along the handle of the malleus.
nerves for the most part accompany the blood-vessels, first supplying these
then forming a plexus both in the cutis and in the mucosa. Lymphatic ve
are, according to Kessel, tolerably abundant in all three layers.

The **inner wall** of the tympanum, which separates it from the inte
ear, is very uneven. Near its upper part is an ovoid, or nearly kidn
shaped opening—*fenestra ovalis* (fig. 375, *f.o*), which leads into the ca
of the vestibule. This opening, which is elongated from before b
wards, with a slight inclination downwards in front, is occupied in
recent state by the base of the stapes, and the annular ligament conne
with that plate of bone. Above the fenestra ovalis, and between it
the roof of the tympanum, a ridge indicates the position of the aque
of Fallopius (*aF*), as it passes backwards, containing the facial n

is a larger and more rounded elevation, caused by the projection
ds of the first turn of the cochlea, and named the *promontory*,
r cochleæ (fig. 375, *p*); its surface is marked by grooves, in which
nerves of the tympanic plexus.

w and behind the promontory, and somewhat hidden by it, is
r aperture named *fenestra rotunda*, which lies within a funnel-
l depression (fig. 375, *f.r*). In the macerated and dried bone the
ra rotunda opens into the scala tympani of the cochlea; but, in the
l state, it is closed by a thin membrane.

Fig. 375.

Fig. 375.—Inner wall of the right tympanum (G. D. Thane). ½

lower end of the Eustachian tube and canal for the tensor tympani is cut open
ly by the saw. *M*, bristle passed into the opening from the tympanum into the
l cells; *f o*, fenestra ovalis; *f r*, fenestra rotunda; *p*, promontory; *a F*, aqueduct
llopius, or canal of the facial nerve; *c.pr*, lower end of the processus cochleariformis,
t, bristle passed through the canal for the tensor tympani muscle; *Eu*, bristle in the
chian tube.

he membrane closing the fenestra rotunda—*secondary membrane of
tympanum* (Scarpa)—is rather concave towards the tympanic cavity,
, like the membrana tympani, is composed of three structures, the
dle being fibrous, and the outer and inner derived from the mem-
nes lining the cavities between which it interposed, viz., the
panum and the cochlea.

The **posterior wall** of the tympanum has at its upper part one larger
g. 375, *M*), and several smaller openings, which lead into irregular
vities, the *mastoid cells*, in the substance of the mastoid portion of the
mporal bone. These cells communicate for the most part freely with
e another, and are lined by a thin mucous membrane continuous with

that of the tympanum. Behind the fenestra ovalis, and directed up is a small conical eminence, called the *pyramid*, or *eminentia pyra* (fig. 374, 375, *py*). Its apex is pierced by a foramen, through whi tendon of the stapedius muscle emerges from a canal which when back is found to turn downwards in the posterior wall of the tymp and to join obliquely the descending part of the aqueduct of Fa (fig. 372, 7). A small bony spiculum often connects the end pyramid with the upper part of the promontory (see fig. 375).

The anterior extremity of the tympanum is narrowed by the g descent of the roof, and is continued into the inner orifice

Fig. 376.

Fig. 376.—Section across the cartilaginous part of the Eustachian tu (Rüdinger).

1, 2, bent cartilaginous plate ; 3, musc. dilatator tubæ ; to the left of 4, part attachment of the levator palati muscle ; 5, tissue uniting the tube to the base skull ; 6, and 7, mucous glands ; 8, 10, fat ; 9 to 11, lumen of the tube ; 12, con tissue on the lateral aspect of the tube.

Eustachian tube (fig. 375). Above the commencement of this canal which lodges the tensor tympani muscle. This canal is abou an inch long, and it opens immediately in front of the fenestra surrounded by the expanded and everted end of the cochleariform p which separates it from the Eustachian tube.

In the recent state the fibrous sheath of the tendon is expanded over the the canal, so as to impart to it a conical shape (see fig. 381, *tt*.)

The **Eustachian tube** (fig. 369, 4) is a canal, bounded partly b partly by cartilage and fibrous membrane, which leads from the c the tympanum to the upper part of the pharynx. From the tymp is directed forwards and inwards, with a slight inclination downwa entire length is about an inch and a half. The posterior or division of the tube is placed at the angle of junction of the portion of the temporal bone with the squamous portion. The part of the tube is formed of a triangular piece of cartilage, the

[illegible] are slightly curled round towards each other, leaving an interval [illegible] under and outer side, in which the wall of the canal is completed [illegible]se but pliable fibrous membrane, and by a muscular band con-[illegible]d with the tensor palati and termed by Rüdinger the *dilatator tubæ*. [illegible]ube is trumpet-shaped, being narrow behind, and gradually expand-[illegible]g a greater width in front; the anterior part is compressed from side [illegible]de, and is fixed to the inner pterygoid plate of the sphenoid bone.

anterior opening is of a compressed oval form, and is placed [illegible]nely at the side and upper part of the pharynx, into which its promi-margin projects behind the lower turbinate bone of the nose, and [illegible]o the level of the hard palate. Through this aperture the mucous [illegible]brane of the pharynx is continuous with that which lines the tym-[illegible]um, and under certain conditions air passes into and out of that cavity.

MALL BONES OF THE EAR.—Three small bones (*ossiculâ auditûs*) are [illegible]ained in the upper part of the tympanum: of these, the outermost [illegible]*leus*) is attached to the membrana tympani; the innermost (*stapes*) [illegible]ted in the fenestra ovalis; and the third (*incus*) placed between the [illegible]r two, is connected to them by articular surfaces. They form to-[illegible]ther an angular and jointed connecting rod between the membrana [illegible]pani and the membrane which closes the fenestra ovalis.

[illegible]he **malleus** or hammer-bone (figs. 377, 378), consists of an upper

Fig. 377.

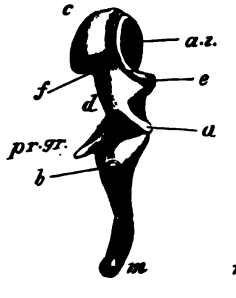


Fig. 378.

[illegible]377.—THE LEFT MALLEUS [illegible]THE ADULT VIEWED FROM [illegible]E OUTER SIDE. MAGNIFIED [illegible]CE TIMES. (After Helm-[illegible]ltz.)

[illegible] capitulum; *a i*, grooved [illegible]ular surface for the incus; [illegible]e prominent lower margin; [illegible]ervix; *m*, end of the manu-[illegible]m; *b*. processus brevis; *pr.gr*, [illegible]ssus gracilis, here repre-[illegible]ed only by a short stump, the [illegible] of the process having been [illegible]erted into ligament; *a*, ridge [illegible]which the external ligament is [illegible]ched.

[illegible]g. 378.—LEFT MALLEUS OF A CHILD VIEWED FROM BEFORE. MAGNIFIED FOUR TIMES. (E.A.S.)

[illegible]he lettering is the same as in the previous figure. The processus gracilis is here [illegible]plete. The angle which the manubrium forms with the rest of the bone is seen in [illegible]view.

[illegible]ker portion, with a tapering lower portion, and two processes. The [illegible]er end is formed by the rounded *head* (capitulum) (*c*), on the [illegible]erior surface of which is an elliptical depressed surface (*a.i*) with [illegible]minent margins, which passes obliquely downwards and inwards, [illegible]serves for articulation with the incus. Below the head is a con-[illegible]ted *neck* (*d*); and beneath this another slight enlargement of the bone, [illegible]hich the processes are attached. The *handle* (*manubrium*) (*m*), the [illegible]r tapering point of the malleus, is slightly twisted, and is compressed [illegible]. before backwards to near its point, where it is flattened laterally. [illegible]rms a rounded obtuse angle with the head of the bone (fig. 378), [illegible]passes downwards, with an inclination forwards and inwards, on [illegible]nner side of the membrana tympani, to which it is closely attached by its periosteal covering and also by a dense fibro-cartilaginous

tissue extending its whole length, except near the root of the p
where the bone is less firmly united to the membrane. The p
insertion of the tendon of the tensor tympani muscle is so
marked by a slight projection on the inner side of the manubrium
its upper end. The *long process* (*processus gracilis* seu *fo*
(*pr.gr.*) is a very slender spiculum of bone, which in the adult is
converted, except a small stump, into ligamentous tissue, and
where it still exists as bone is often broken off in its removal fro
tympanum; it projects at nearly a right angle from the front o
neck of the malleus, and extends thence obliquely downwards and
wards to the Glaserian fissure. Its end is flattened and expanded,
is connected by ligamentous fibres or bone to the sides of the f
The *short process* (*processus brevis* vel *obtusus*) (*b*) is a low c
eminence situated at the root of the manubrium, beneath the c
and projecting outwards towards the upper part of the mem
tympani, to which it is attached.

The **incus** (fig. 379), as its name implies, has been compared to

Fig. 379.

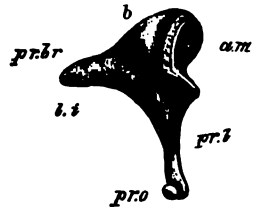


Fig. 379.—LEFT INCUS, VIEWED FROM THE INNER AND SOMEWHAT FROM BEFORE. MAGNIFIED FOUR (G. D. Thane).

b, body; *a m*, ridged articular surface for the ma
pr. br, processus brevis; *l. i*, rough surface
extremity for the attachment of the ligament o
incus; *pr. l*, processus longus, terminating belo
small projection which comes off from it at a
angle, and is capped by a convex tubercle,
orbicularis, *pr. o*, for articulation with the stapes.

anvil; but it resembles perhaps more nearly a tooth with two fangs wi
separated. It consists of a body and two processes. The *body*
deep saddle-shaped articular surface in front (*a. m*), which fits a
the head of the malleus. The *shorter process* (*crus breve*) (*pr.br.*) o
incus projects backwards. Its extremity is tipped with cartilage, and
moveably articulated by ligamentous fibres with the posterior and
with the outer wall of the tympanum near the entrance to the mastoid c
The *long process* (*crus longum*) (*pr.l*) tapers rather more gradually,
passes downwards and inwards behind and parallel to the handle of
malleus: at its extremity it is bent inwards, and is suddenly narrowe
into a short neck; and upon this is set a flattened tubercle (*process*
orbicularis seu *lenticularis*) (*pr.o*), tipped with cartilage. This tubercle,
which articulates with the head of the stapes, was formerly, under the
name of *os orbiculare* seu *lenticulare*, described as a separate bone, which
indeed it originally is in childhood.

At the joints between the incus and malleus on the one hand and the incus and stapes on the other the articular surfaces are tipped with cartilage and enclosed by a synovial membrane. Rüdinger describes both in this joint and in the articulation of the incus with the stapes an interarticular fibro-cartilage, which subdivides the joint into two parts.

The **stapes** (fig. 380), the third and innermost bone of the ear, is in shape remarkably like a stirrup, and is composed of a head, a base, and two crura. The *head* (*h*) is directed outwards, and has on its end a slight depression, covered with cartilage, which articulates with the lenticular process of the incus. The *base* (*b*) is a plate of bone fitting into

notch of Rivini, and converge to the short process and adjacent p of the body of the malleus.

The posterior bundle of fibres of this ligament together with the anterior bundle of the anterior ligament are termed by Helmholtz the "axis-ligament of the malleus," since they are attached nearly in the axis of rotation of that bone.

Fig. 381.

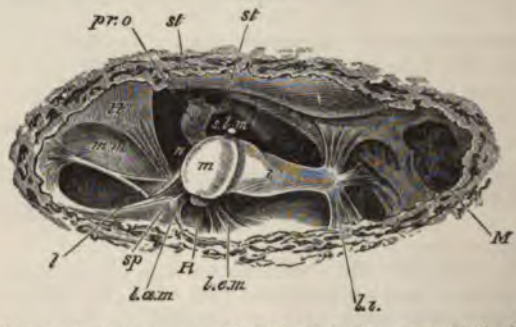


Fig. 381.—View of the CAVITY OF THE TYMPANUM, OPENED FROM ABOVE. (MAGNIFIED FOUR TIMES.) (E. A. S.)

m, head of the malleus; *s p*, spina tympanica major; *l. a. m*, anterior ligament of the malleus; *l. e. m*, external ligament of the malleus; *R*, gap between the two ligaments leading to the membrana tympani and notch of Rivini; *M*, body of the incus; *l. i*, posterior ligament of the incus; *pr. o*, processus orbicularis of the incus seen in the depth of the cavity, articulating with the head of the stapes, *st*; *st'*, tendon of the stapedius muscle emerging from the pyramid; *tt*, tendon of the tensor tympani, emerging from the conical end of its canal; *l*, thickened edge of a flattened band of ligamentous fibres which lies in a fold of the mucous membrane, *m.m.*, and assists in fixing the malleus; *s. l. m*, superior ligament of the malleus, cut short; *n*, chorda tympani nerve.

The *superior ligament of the malleus* (figs. 374, *l.s.*, and 381, 382. *s. l. m.*) consists of a small bundle of fibres, which passes downwards and outwards from the roof of the tympanum to the head of the malleus, and serves to check the outward movements of the manubrium and membrana tympani.

Inferior ligament of the malleus.—A small bundle of ligamentous fibres is frequently found passing from near the extremity of the handle of the malleus upwards and backwards behind the long process of the incus, to be attached to the outer wall of the tympanum. This ligament assists the external ligament in resisting a too violent action of the tensor tympani muscle, and it serves also to restrict any rotating action which that muscle may tend to exert upon the malleus (E.A.S.).

The *ligament of the incus* (figs. 374, 381, *l. i*) extends from near the point of the short crus backwards towards the posterior wall of the tympanum, but some of its fibres spread also outwards and inwards. It is attached below the entrance to the mastoid cells.

Muscles.—There are only two well-determined muscles of the tympanum. Sömmerring described four, and some authors have mentioned a larger number; but their descriptions have not been confirmed by later research. Of the two muscles generally recognised, one is attached to the malleus, and the other to the stapes.

The *tensor tympani* (fig. 381, *tt*), is the larger of these muscles. It consists of a tapering fleshy part, about half an inch in length, and a slender tendon. The muscular fibres arise from the cartilaginous end of the Eustachian tube and the adjoining surface of the sphenoid bone, and from the sides of the canal in which the muscle lies and in which it is conducted backwards to the cavity of the tympanum. Immediately in front of the fenestra ovalis the tendon of the muscle bends at nearly a right angle over the end of the processus cochleariformis as round a

alley, and, contained in a fibrous sheath, passes outwards, to be inserted to the inner part of the handle of the malleus, close to its root.

The *stapedius* is a very distinct muscle, but is hid within the bone, being lodged in the descending part of the aqueductus Fallopii and in the hollow of the pyramid. The tendon issues from the aperture at the apex of that little elevation (fig. 374), and passing forwards, surrounded by a fibrous sheath, is inserted into the neck of the stapes posteriorly, close to the articulation of that bone with the lenticular process of the incus.

A very slender spine of bone has been found occasionally in the tendon of the stapedius in man: and a similar piece of bone, though of a rounder shape, exists constantly in the horse, the ox, and other animals.

Fig. 382.

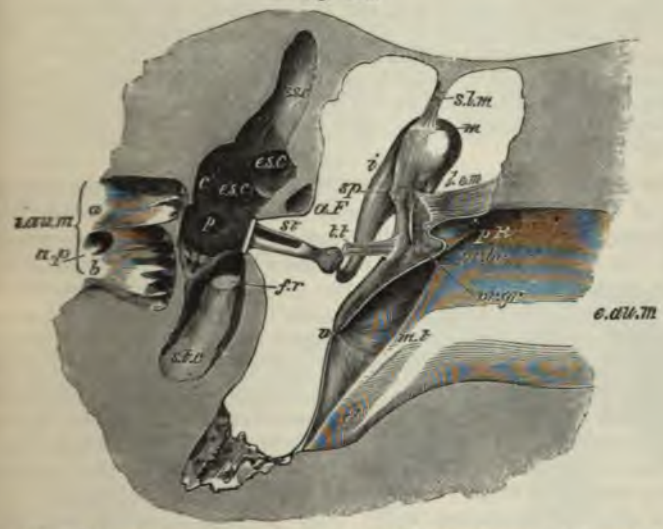


Fig. 382.—PROFILE VIEW OF THE LEFT MEMBRANA TYMPANI AND AUDITORY OSSICLES FROM BEFORE AND SOMEWHAT FROM ABOVE. MAGNIFIED FOUR TIMES. (E. A. S.)

The anterior half of the membrane has been cut away by an oblique slice. *m*, head of the malleus; *sp*, spur-like projection of the lower border of its articular surface; *pr. br*, its short process; *pr. gr*, root of processus gracilis, cut; *s.l.m*, suspensory ligament of the malleus; *l.e.m*, its external ligament; *t.t*, tendon of the tensor tympani, cut; *i*, incus, its long process; *st*, stapes in fenestra ovalis; *e.au.m*, external auditory meatus; *p.R*, notch of Rivini; *m.t*, membrana tympani; *u*, its most depressed point or umbo; *d*, declivity at the extremity of the external meatus; *i.au.m*, internal auditory meatus; *a* and *b*, its upper and lower divisions for the corresponding parts of the auditory nerve; *a.p*, canal for the nerve to the ampulla of the posterior semicircular canal; *s.s.c*, ampullary end of the superior canal; *p*, ampullary opening of the posterior canal; *c*, common aperture of the superior and posterior canals; *e.s.c*, ampullary, and *e'.s.c*, non-ampullary end of the external canal; *s.t.c*, scala tympani cochleæ; *f.r*, fenestra rotunda, closed by its membrane; *a.F*, aqueduct of Fallopius.

Movements of the auditory ossicles.—The malleus and incus move together round an axis extending backwards from the attachment of the malleus by its anterior ligaments to the attachment of the short process of the incus posteriorly. The handle of the malleus follows all the movements of the membrana tympani, and when the membrane is impelled inwards, the incus, moving inwards along with the malleus, pushes the stapes inwards towards the internal ear. In this movement the head of the stapes is slightly raised as well as pressed inwards, and the upper margin of its base moves more than the lower.

But the cavity of the inner ear is full of liquid; and its walls are unyi
except at the fenestra rotunda; when, therefore, the stapes is pushed in
the secondary membrane of the tympanum, which blocks up the fenestra ro
must be bulged outwards. When the membrana tympani returns to its o
condition these movements are reversed. That the movement inwards of the
must closely accompany that of the malleus, is necessitated by the fact th
lower margin of its articular surface has a well marked projection which o
against the prominent border of the articular surface of the malleus (fig. 3
If, however, in consequence of increase of tension of the air in the tym
the malleus should be moved too freely outwards, the incus need not follow
movement to its full extent, but may merely glide over the smooth adja
surface of the malleus, and thus the danger that there would otherwise b
forcibly dragging out the stapes from the fenestra ovalis is avoided.

The tensor tympani muscle, being attached near the base of the manubri
the malleus, draws the whole bone and the membrane inwards, tightening
latter. Its action is opposed by the strong external ligament of the m
The tensor tympani exerts but little rotating action upon the malleus. The a
of the stapedius muscle is obviously to draw the head of the stapes back
in doing which the hinder end of the base of that bone will be pressed ag
the margin of the fenestra ovalis, while the fore part will be withdrawn fr
the fenestra.

The lining membrane of the tympanum.—The mucous m
brane of the tympanum is continuous with that of the pharynx thro
the Eustachian tube, and is further prolonged from the tympanum ba
wards into the mastoid cells. Two folds which cross the breadth of t
cavity descend from the part of the membrane which lines the roo
The anterior fold turns round the tendon of the tensor tympani muscl
the posterior fold passes round the stapes. The malleus and incus a
invested by the lining of the outer wall of the cavity; which for
also prominent folds in front of and behind the neck of the malle
these folds separating off a small pouch-like corner of the tympa
cavity corresponding with the situation of the membrana flaccid
Various other smaller folds are met with, and they for the most pa
contain strands of fibrous tissue and sometimes osseous spicules.

The mucous membrane which lines the cartilaginous part of the
Eustachian tube resembles much the membrane of the pharynx, wit
which it is immediately continuous; it is thick and vascular, is covered
by ciliated epithelium, and is provided with many simple mucous glands
which pour out a thick secretion: in the osseous part of the tube, however,
the membrane becomes gradually thinner. In the tympanum and the
mastoid cells the mucous membrane is paler, thinner, and less vascular,
and secretes a less viscid, somewhat yellow fluid. Between it and the
periosteum is a network of fibrous bundles, which are here and there
raised above the general surface, causing corresponding projections of
the mucous membrane. In various places on the interlacing bundles,
peculiar swellings occur of various sizes, which appear to be caused by
the superaddition of concentrically arranged fibres upon the smaller
bundles, and produce an appearance similar to that of miniature Pacinian
corpuscles (Politzer, Kessel). The epithelium in the tympanic cavity is
in part columnar and ciliated, but the roof, the promontory, the ossicula,
and the membrana, are covered with a simple layer of flattened non-
ciliated cells (v. Troeltsch).

Vessels and Nerves of the Tympanum.—The arteries of the tympanum,
though very small, are numerous, and are derived from branches of the external,
and from the internal carotid.

art of the cavity is supplied chiefly by the *tympanic branch* of the dillary, which enters by the fissure of Glaser. The back part of the ding the mastoid cells, receives its arteries from the *stylo-mastoid* e posterior auricular artery, which is conducted to the tympanum by t of Fallopius. These two arteries form by their anastomosis ircle round the margin of the membrana tympani. The smaller the tympanum are, the *petrosal branch* of the middle meningeal, through the *hiatus Fallopii*, and branches through the bone *from the otid* artery, furnished from that vessel whilst in the carotid canal.

of the tympanum empty their contents into the superior petrosal e temporo-maxillary vein.

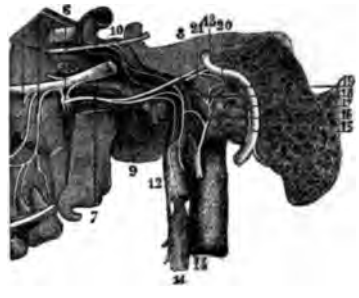
-The tympanum contains numerous nerves; for, besides those which arts of the middle ear itself, there are several which serve merely to res of different origin.

g membrane of the tympanum is supplied by filaments from the exus, which occupies the shallow grooves on the inner wall of the cularly on the surface of the promontory (fig. 375).

us (fig. 383) is formed by 1st, the nerve of Jacobson from the glion of the glosso-pharyngeal; 2nd, a filament connecting the cobson with the carotid plexus of the sympathetic; 3rd, a branch the great superficial petrosal nerve; 4th and lastly, the small superal nerve, passing to the otic ganglion.

ganglion cells are found both in the uniting cords and also at the action of the plexus.

Fig. 383.



IEW OF THE TYMPANIC PLEXUS (from Sappey, after Hirschveillé).

palatine ganglion; 7, Vidian eat superficial petrosal nerve; anch of the Vidian nerve; 10, ixth nerve connected by twigs pathetic; 11, superior cervical the sympathetic; 12, carotid acial nerve; 14, glosso-pharyn-5, nerve of Jacobson; 16, its sympathetic; 17, filament to rotunda; 18, filament to the tube; 19, filament to the s; 20, small superficial petro-21, filament joining large trosal.

of Jacobson (fig. 383, 15) enters the tympanum by a small foramen r, which forms the upper end of a short canal in the petrous portion oral bone, beginning at the base of the skull between the carotid l the jugular fossa. The nerve from the carotid plexus is above of this, and passes through the bone directly from the carotid canal.

to the great superficial petrosal nerve (fig. 383, 21) is lodged in a opens on the inner wall of the tympanum in front of the fenestra small superficial petrosal nerve also leaves at the fore part of the th the canal for the tensor tympani.

r tympani muscle obtains its nerve from the otic ganglion; and the eives filaments from the facial nerve.

s tympani arising from the facial near the lower end of the aqueopius, takes a recurrent course to the tympanum, which it enters by an he posterior wall just below the level of the pyramid. From this place h a slight curve across the cavity near the outer boundary, and crossing the posterior part of the membrana tympani, the handle of the malleus k, and the processus gracilis of the same bone, finally enters a small bone close to the Glaserian fissure (fig. 374, *ch*). It is invested by the lining membrane already mentioned as occurring in this situation.

at the lower and back part of the vestibule; and the op terminates in the common canal above described. The ex circular canal (fig. 384, 4; fig. 385, 7) arches *horizontally* and opens by two distinct orifices into the upper and back p vestibule. The canal is shorter than either of the other two: is at the outer end, above the fenestra ovalis.

The **cochlea** (fig. 384, 6, 7, 8), when cleared of the surroundir bony substance in which it lies embedded, appears in the form cone, the base of which is turned towards the internal audit whilst the apex is directed outwards, with an inclination fo downwards, and is close to the canal for the tensor tympani measures about ¼ of an inch in length, and the same in breadth

Fig. 387.

Fig. 387.—Osseous Labyrinth of the bar flammea) (from Breschet). ⅔

1, semicircular canals; 2, vestibule; 3, cochl of a short straight tube.

It consists of a gradually tapering spir inner wall of which is formed by a cent or *modiolus* (fig. 388, 1), around whic It is partially divided along its whole spiral lamina (2), projecting into it modiolus. From this osseous spiral la branous structures are in the recen stretched across to the outer wall of th thus completely separate two passage one on each side of the spiral lamina, which communicat the other only by a small opening, named *helicotrema*, placed of the cochlea.

That the cochlea is justly to be considered as an elongated tube, c on the modiolus, is illustrated by the simple pouch-like form of the cochlea of birds (fig. 387) as well as by the history of its developme

The *spiral osseous canal* is nearly 1½ inch long, and about diameter at the commencement, where it is widest. From the canal makes 2½ turns round the central pillar (from left the right ear, and in the opposite direction in the left ear, su

Fig. 388.

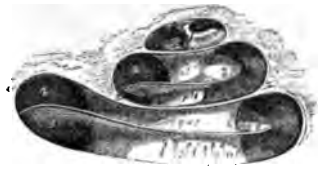


Fig. 389.

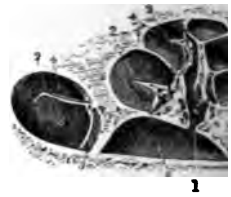


Fig. 388.—Diagrammatic view of the osseous cochlea laid opi

1, modiolus or central pillar; 2, placed on three turns of the lamina spi tympani; 4, scala vestibuli.

Fig. 389.—View of the osseus cochlea divided through the m (from Arnold). ⅔

1, central canal of the modiolus; 2, lamina spiralis ossea; 3, scala tym vestibuli; 5, porous substance of the modiolus; 6, end of the internal au

wed from the base), and ends by an arched and closed ex-
led the *cupola*, which forms the summit of the cochlea. The
aving by far the most extensive curve and being the largest
the tube, nearly hides the second from view; and, bulging
into the tympanum, forms the round elevation on the inner
t cavity called the promontory.

iolus (columella cochleæ), the central pillar or axis of the
much the thickest within the first turn of the tube, rapidly
g in size in the succeeding parts. Its central part is spongy
ie last half coil, and is pierced by many small canals, for the
the nerves and vessels to the spiral lamina; one of these
ger than the rest, *central canal of the modiolus*, runs from the
gh the centre of the modiolus (fig. 389, 1).

ous spiral lamina is a thin, flat plate, growing from the modi-
rojecting into the spiral tube, so as to divide it partly into
oes not reach farther than about half-way towards the outer
spiral tube. Close to the apex of the cochlea, it ends in a
rocess (*hamulus*), which partly bounds the helicotrema.

ina is thin and dense at its free edge; but nearer the modi
ternal structure is more open and spongy, and contains
small canals for vessels and nerves, continuous with, but
right angles to, the canals in the modiolus. Winding round
us, in the base of the spiral lamina, is a small canal, named
anal of the modiolus.

a tympani (fig. 388, 3), the portion of the tube on the basal
lamina spiralis, commences at the fenestra rotunda, where in
state it is separated from the tympanum by the secondary
of the tympanum. Close to its commencement is the orifice
canal (*aqueductus cochleæ*, fig. 385, 9), which extends down-
inwards through the substance of the petrous bone to the
sa, to which it transmits a small vein. There is also a com-
through it between the scala tympani and the subarachnoid
e *scala vestibuli* (fig. 388, 4) is rather narrower than the scala
the first turn of the cochlea; it commences from the cavity
ibule, and communicates, as already described, with the scala
the apex of the modiolus.

THE MEMBRANOUS LABYRINTH.

he osseous labyrinth, and separated in most parts from its
nbrane by the perilymph, membranous structures exist in
ltimate ramifications of the auditory nerve are spread. In
le and semicircular canals these structures have a general re-
n form to the complicated cavity in which they are contained.
t, however, lie loose within the osseous cavity, but along the
ler of the canals, and at the places of entrance of the nerves
stibule and ampullæ are fixed to its wall. In the cochlea
anous structures complete the septum between the scalæ
ıtioned, and enclose an intermediate passage, the membranous
cochlea. As before stated, the liquid contained within the
s labyrinth is distinguished as *endolymph*.

which contains the perilymph communicates through the sheath of
nerve with both the subdural and subarachnoid spaces.

E.—Within the *osseous* vestibule are two membranous sacs,

the one of which, termed the *utricle*, is connected with the s canals, whilst the other, the *saccule*, is connected with the coch two sacs although in close contact do not open directly into o although they are in indirect communication, in a manner p be explained.

The larger of the two sacs, the *common sinus* or **utricle** (f is of an oblong form, slightly flattened from without inw lodged in the upper and back part of the vestibule, occupyin hemi-elliptica and the space immediately below this. Opposit vestibuli several small branches of the auditory nerve ente

Fig. 390.

Fig. 390.—PLAN OF THE BRANOUS LABYRINTH THE MESIAL ASPECT

u, utricle, with its n three semicircular cana ampullæ; *s*, saccule; *aq.* vestibuli; *s. c.* saccus cus; *c. r.* canalis reunie of the cochlea.

foramina in the bon the walls of the com are thicker and m than elsewhere (*macula acustica*). A small mass of calcareo (*otoliths* or *otoconia*) lies within the sac, attached to its walls at These otoliths are crystals of carbonate of lime, rhombic, oct six-sided, often pointed at their extremities.

The ends of all the membranous semicircular canals ope utricle.

The small vestibular vesicle, the **saccule** (fig. 390, *s*), is n spherical than the common sinus, but, like it, is somewhat flatt saccule is situated in the lower and fore part of the cavity of t

Fig. 391.

Fig. 391.—MEMBRANOUS LAB NERVOUS TWIGS DETACHED, (Breschet).

k, facial nerve in the meat internus; *l*, anterior division tory nerve giving branches, o, utricle and the ampullæ of and external canals; *l'*, vestib of the auditory nerve, giving a the saccule, another to the p pulla, *q*, and a third (*r*) to th *a*, *b*, *c*, ampullæ of the superi and posterior semicircular c tively; *d*, the united part of and posterior canals; *e*, the utricle; *f*, the saccule.

vestibule, close to the op the scala vestibuli of the c is received into the hol fovea hemispherica, from of which many branches of nerve enter it, and here there macula in its wall. It also contains a small mass of otoliths.

The saccule is connected with the membranous canal of the cochlea by means of a short narrow canal, the *canalis reuniens* of Hensen (*c. r.*). There is also a minute canal, lined with epithelium, which passes from the utricle along the aqueductus vestibuli to end blindly in a dilated extremity (saccus endo-lymphaticus (*s.e.*)) on the posterior surface of the petrous bone just below the orifice of the aqueduct and lying in the fold of the dura mater. This canal is joined near its origin by a small tube from the saccule, so that in this way the cavity of the saccule is brought into communication with that of the utricle (Boettcher).

SEMICIRCULAR CANALS.—The **membranous semicircular canals** are from one-third to one-fifth the diameter of the osseous tubes in which they are lodged, and are dilated into ampullæ within the ampullary enlargements of those tubes. In section they are oval or somewhat elliptical (fig. 392). At the ampullæ they are thicker and less translucent than in the rest of their extent, and nearly fill their bony cases. That part of each which is towards the concavity of the semicircle of the canal is free; but the opposite portion is fixed to the wall of the bony canal; in the ampulla this part is flattened and receives branches of nerves and blood-vessels, and on its inner surface is a transverse projection, (*crista acustica*) which partly divides the cavity into two.

Auditory nerve.—Within the internal auditory meatus the auditory nerve divides into two branches, which, broken up into minute filaments, pass through the perforations of the cribriform plate which separates the meatus from the internal ear, and are distributed respectively to the cochlea and vestibule. In both branches, as well as in the trunk, there are numerous nerve-cells. The superior division (fig. 391, *l*), which is at first also anterior in position and is separated by a crest of bone from the other division below it, gives off three branches, which proceed respectively to the utricle and the ampullæ of the superior and external semicircular canals, entering the vestibular cavity in a group among the crista vestibuli. The inferior division on the other hand (*l'*), which is at first behind as well as below the vestibular division, gives off, besides the numerous fibres which enter the cochlea by the tractus foraminulentus, a branch for the saccule—which enters the vestibule by a small group of foramina, which open at the bottom of the fovea hemispherica—and the branch for the posterior semicircular canal which is long and slender, and traverses a small passage in the bone behind the foramina for the nerve of the sacculus. The nerves of the ampullæ enter the flattened or least prominent side of the ampullæ, where they each form a forked swelling, which corresponds with the crista acustica, in the interior of the dilatation. No nerves have been found extending to any other parts of the semicircular canals.

Vessels of the labyrinth.—The *internal auditory artery*, a branch of the basilar, accompanies the auditory nerve in the internal auditory meatus, and divides into branches for the vestibule and cochlea. Those of the vestibule supply the membranous labyrinth and the endosteum, and small vessels ensheathed by bone tissue pass across the cavity containing the perilymph. The blood is chiefly collected into the internal auditory veins which accompany the artery and open into the inferior petrosal or the transverse sinus, but some is conveyed to the superior petrosal sinus by fine veins in the aqueductus vestibuli.

Structure of the membranous labyrinth.—Three layers can be distinguished in the membranous walls of the semicircular canals, an

Fig. 392.

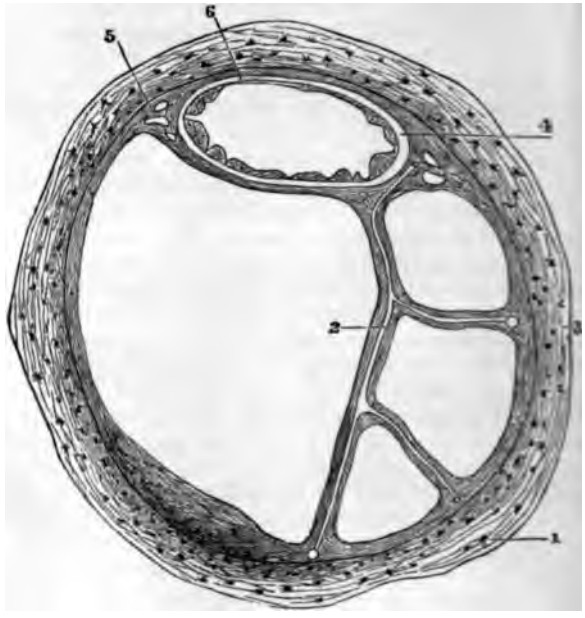


Fig. 392.—Section of one of the human semicircular canals (Rüdinger Magnified.

1, osseous wall; 2, fibrous bands with included blood-vessels, united at 3 w periosteum; 4, membranous canal with its three layers; 5, short fibrous band intervening spaces) uniting the membranous canal firmly to the periosteum; 6, its outermost layer with the periosteum.

Fig. 393.

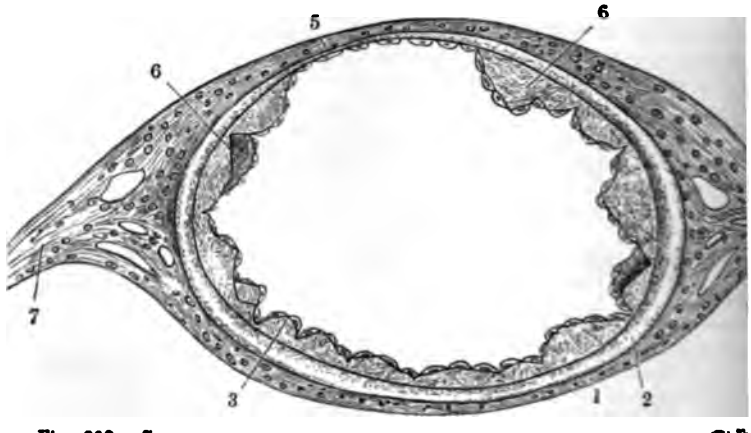


Fig. 393.—Section of membranous semicircular canal, much magnified (Rüdi

1, outer fibrous layer; 2, tunica propria; 3, 6, papilliform projections with epi covering; 5, fixed side of the canal, with very thin tunica propria without pa 7, fibrous bands passing to periosteum.

er fibrous stratum, an inner epithelial lining, and between the two a
ica propria. These layers are not of equal thickness throughout, for
g the side which is in contact with and supported by the bone
= 392, 6), they are thinner than at the rest of the circumference,
re they lie free and are bathed by the perilymph. The difference in
kness affects the fibrous layer and the tunica propria only, for the
helium forms throughout a lining of simple flattened cells.

The *fibrous layer* (fig. 392, 1), which contains some irregular pigment-
s, is apparently composed of ordinary fibrous tissue, similar to that
the periosteum, with which it becomes continuous at the parts
ere the two structures are in contact. It is especially developed at
ends of the oval section, whence well-marked bands of fibrous
ue pass to the periosteum (fig. 392, 7). More delicate bands of
rous tissue traverse the perilymph to become connected with the peri-
eum of the opposite wall of the canal (fig. 392, 2). Both along these
ds and also more directly from the contiguous periosteum, numerous
all blood-vessels pass into the fibrous layer and there break up into a
rse capillary network, the branches of which do not, in man, pass into
tunica propria.

The *tunica propria* is a clear membranous structure continuous
und the whole tube, although thinning off very much opposite the
rt where the membranous canal is in contact with the bone (fig.
3, 5). Externally it is not very distinctly marked off from the fibrous
t: internally it has a number of papilliform eminences (fig. 393, 3,
which project into the interior of the canal except at the thinnest
rt (Rüdinger).

The *epithelial lining* takes the form of a complete layer of flattened
ls, which in the human semicircular canals are of the same nature
roughout.

In many of the lower animals—birds and fishes—some of these lining cells are
umnar, while in one species of fish, (Salmo hucho), as described by Rüdinger,
act along the whole length of each canal becomes developed into two rows of
nded cells, from each of which a long filament extends to the wall of the
al in a direction transverse to the axis.

The meaning of these modifications of structure is unknown. No nerves have
herto been seen proceeding to the parts in question; but they apparently
resent the much more developed peculiarly modified epithelium which, as we
ll immediately see, is found in the ampullæ and in the saccule and utricle
posite the parts where the branches of the auditory nerve enter, and which
ives the ultimate terminations of those nerves.

The ampullæ, as well as the saccule and utricle, agree generally in
ucture with the semicircular canals: but at the part where they are
nected to the osseous wall the fibrous outer layer is looser, and the
ica propria is much thickened, and in the ampullæ projects into
cavity as the *septum transversum* or *crista acustica*, before mentioned.
rough the substance of this thickening the nerve-fibres pass to the
e of the ridge, and over it the epithelium is of an elongated columnar
m (fig. 394), and is surmounted by long, conical, gradually tapering
ments (auditory hairs (*h*)), which project stiffly into the cavity.
ese hairs are borne by the columnar epithelium-cells, a single hair
jecting from each cell, but under the influence of reagents they are
to become broken near the base, and this splits up into fine fibrils
ich then appear as a bunch of cilium-like filaments attached to the

free border of the cell (fig. 395, *h*, *h'*). The columnar cells, or hair do not extend down to the basement membrane, but terminate this in a somewhat pointed extremity. They are directly connect this extremity with branches of the nerve-fibres which penetrate in epithelium (fig. 395, *n*). This connection has been described by R in reptiles and there is little doubt it obtains in all vertebrates.

Fig. 394.

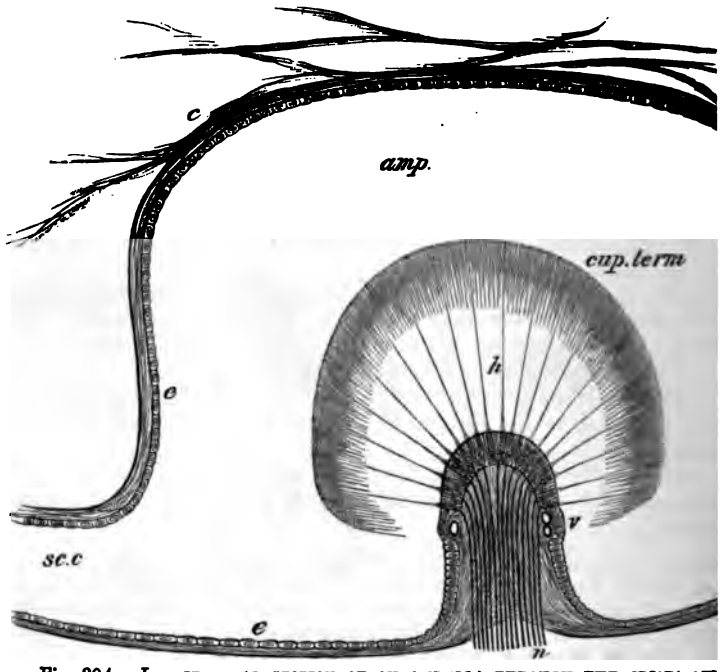


Fig. 394.—Longitudinal section of an ampulla through the crista acu Semi-diagrammatic (E. A. S.).

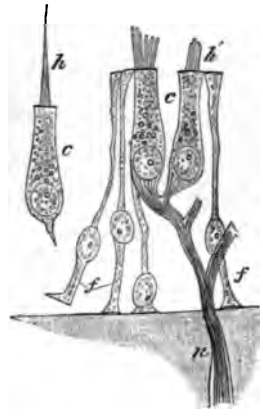
amp, cavity of the ampulla; *sc. c*, semicircular canal opening out of it; *c*, co tissue attached to the wall of the membranous ampulla and traversing the pa *e e*, flattened epithelium of ampulla; *h*, auditory hairs projecting from the colum of the auditory epithelium into the cupula, *cup. term.*; *v*, a vascula stria mar limit of the auditory epithelium on the crista; *n*, nerve-fibres entering the ba crista and passing into the columnar cells.

Between and beneath the columnar cells other cells are met a different character. They take the form of long and compa rigid fibres (*fibre-cells* of Retzius) which extend through th thickness of the epithelium, and are provided at one part c course with a nucleated enlargement. This is always placed be columnar cells, and in many it is close to the central end of th The fibres, which are probably sustentacular in function, like th of Müller in the retina, expand slightly as they approach the f face, and appear to become attached to a cuticular structur encloses the ends of the hair-cells and is thus comparable to the r lamina of the cochlea (Urban Pritchard). On the other hand th are set by their central ends upon a limiting membrane which

pithelium next to the tunica propria, and which appears in section ine but well-marked line.

limits of the auditory epithelium at the sides of the crest appear to be marked, st in the human ampullæ, by a prominent vascular stria (fig. 394, *r*) (E.A.S.).

Fig. 395.



95.—AUDITORY EPITHELIUM FROM THE MACULA ITICA OF THE SACCULE OF A REPTILE (Retzius). HLY MAGNIFIED.

columnar cells; *ff*, fibre-cells; *n*, nerve-fibre, its medullary sheath and passing to terminate in lunar auditory cells; *h*, auditory hair; *h'*, base itory hairs, split up into fibrils.

auditory hairs were first noticed by Max ze, and were believed at first to be connected the elongated cells and not with those of a ar shape. Their true relations were pointed Retzius, and in this matter my own observa- in the fish and in man, entirely coincide with When the cells are isolated after preservation ic acid, the separated columnar cells are alone unted by auditory hairs, whereas the elongated diate cells are not provided with auditory nts. Urban Pritchard has rightly figured sustentacular cells in the cat as expanding e so-called reticular lamina, but his descrip- f their continuity with auditory filaments is not borne out by subse- investigations. It is worthy of note that the auditory hairs do not t freely into the endolymph of the ampulla, but into a soft material which a dome-like shape (cupula terminalis, Lang), and appears to possess an inctly fibrillar structure. It is not possible therefore to suppose that the can be set in vibration singly, but whatever movements are communicated endolymph, must affect the whole cupula and all the hairs embedded (E.A.S.).

foregoing description, although referring more particularly to the characters epithelium and mode of nerve-distribution in the cristæ acusticæ of the llæ, is equally applicable to the maculæ acusticæ of the saccule and utricle. erves which are supplied to the maculæ seem, however, to spread out more those to the ampullæ. As before mentioned, both saccule and utricle in in their cavity and lying in contact with the nerve-epithelium a little of otoliths, which, however, do not float free in the fluid, but appear ded in a soft matrix which again may be enclosed in a delicate cuticular ment. Otoliths are also found scattered here and there in the ampullæ and rcular canals.

CHLEA.—The **membranous cochlea** resembles the membranous ircular canals just described in consisting of a tube, lined by lium and containing endolymph, partly surrounded by a clear containing perilymph, but it differs from them both in shape and e modifications presented by its epithelial lining. In macerated nens, the two parts into which the osseous tube of the cochlea is d are, it will be remembered, only imperfectly separated by the s spiral lamina which projects from the columella; but in the pecimen the tube is separated completely into three distinct parts ans of two membranes, which extend along its whole length (figs. 398). In the first place the lamina spiralis is directly prolonged omparatively strong, well-marked membrane, the *basilar membrane*

(fig. 398, *b*), which stretches straight across to the outer wall cochlea, and is here connected to an inward projection of the lini osteum and sub-periosteal tissue known as the *spiral ligame* The basilar membrane thus helps to complete the upper* limi

Fig. 396.

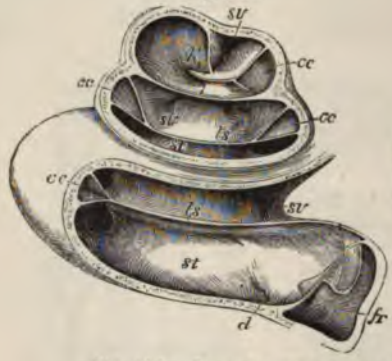


Fig. 397.

Fig. 396.—Left cochlea of a child some weeks old (Reichert).

The drawing was taken from a specimen which had been preserved in alcohol afterwards dried; a section is made so as to show the lamina spiralis, s cochlear canal in each of the three coils: the membranous spiral lamina is pres the appearances connected with the organ of Corti, &c., have been lost fro *f r*, fenestra rotunda with its membrane; *s t*, scala tympani; *s v*, scala vesti lamina spiralis; *h*, hamulus; *c c*, canalis cochleæ; *d*, opening of the a cochleæ.

Fig. 397.—Vertical section of the cochlea of a fœtal calf (Kölliker

In this specimen the external wall was ossified, but the modiolus and spir was still cartilaginous; the section shows in each part of the cochlear tub scalæ with the intermediate canalis cochleæ and lamina spiralis.

scala tympani (*ST*), but does not properly speaking enter into th boundary of the scala vestibuli, for a second, much more delica

Fig. 398.

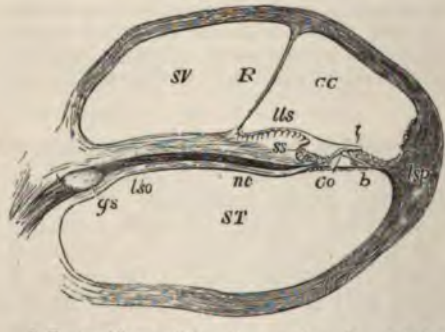


Fig. 398.—Section thr of the coils of the diagrammatic (alter Henle). 30

S T, scala tympani; vestibuli; *C C*, canalis co membrane of Reissner f vestibular wall; *l s o*, lami ossea; *l l s*, limbus lamin *s s*, sulcus spiralis; *n* nerve; *g s*, ganglion membrana tectoria; *b*, basilaris; *C o*, rods of Co ligamentum spirale.

* To avoid repetition it may here be stated that for convenience sake t is considered in the present description as having its larger part or base lowe the domed extremity uppermost, although of course this is far from being t position of the parts whilst within the body. Moreover, parts nearer the col spoken of as *inner*; parts nearer the external wall as *outer*.

known as the membrane of Reissner (*R*) passes from the upper of the lamina a little distance from its end, and stretches obliquely rds and outwards, also to become connected with the lining peri- m. The oblique direction of the membrane of Reissner causes a gular space to be shut off between it and the basilar membrane, ch is bounded externally by the outer osseous wall of the cochlea d by periosteum: and this space, extending throughout the whole th of the osseous tube, and lined throughout by an epithelium ly modified in different parts, is known distinctively as the *canal cochlea, canalis membranaceus*, or *ductus cochlearis* (figs. 397, 398, 400, *DC*). It terminates in a blind pointed extremity at the d another at the base. That at the apex, extending beyond nulus, is fixed to the wall of the cupola, and partly bounds the trema; that at the base fits into the angle at the commencement osseous spiral lamina in front of the floor of the vestibule. Near blind extremity the canal of the cochlea receives a small canal, with epithelium, *canalis reuniens* (Hensen), which is continued the saccule of the vestibule like the neck of a flask, and enters the al of the cochlea abruptly nearly at a right angle (fig. 390, *cr*). The ity of the canal of the cochlea is thus rendered continuous with that the saccule. The structures which are found upon the *floor* of this rally-wound triangular canal of the cochlea claim more particular ntion, for it is to them that the branches of the cochlear nerve are tributed, and upon them the function of the cochlea as a part of the ditory apparatus appears more especially dependent.

The floor itself of the cochlear canal is formed of a narrow portion of e spiral lamina external to the membrane of Reissner, and of the basilar mbrane. In the macerated specimen this part of the lamina thins off adually to a fine edge like the blade of a knife, but in the recent con- tion (fig. 398, *lls*) it retains its thickness for some distance (or even hibits a slight increase), and then abruptly terminates with a border hich in section is C-shaped, with the lower limb of the C much more olonged and tapering than the upper. The lower limb is in fact the ction of the end of the osseous lamina, together with a thin mem- anous layer which covers it, and which is directly prolonged into the silar membrane. This membrane, as well as the whole thickened pper part of the edge of the spiral lamina, not being ossified, disappears the process of maceration. The thickened part (fig. 398, *lls*), with its mewhat overhanging, crest-like end (fig. 400, *Cr*), is known as the *mbus* of the spiral lamina, and the groove which it overhangs, and hich in section is represented by the bay of the C, is known as the *iral groove* (fig. 398, *ss*, fig. 400, *S. sp. i*).

The tissue of which the **limbus** is composed seems to be a form of nnective tissue. Towards the under and inner part there are numerous rpuscles, and the texture is fibrous, but above and near the crest few no connective tissue corpuscles are met with, but the tissue has a lumnar aspect with somewhat regularly arranged nuclei. The fibrillated sue is prolonged, as just intimated, beyond the osseous lamina, into e basilar membrane. Near its termination, close to the junction with e basilar membrane, it is perforated with a number of regularly-arranged, ngated apertures (fig. 399, *p*), which serve for the transmission up- rds of the nerve-fibres. The latter, in their course from the spiral nglion to the auditory epithelium, are lodged, as far as this, in canals

in the lower osseous part of the spiral lamina. Their arrangem
be afterwards more fully described.

When the limbus is viewed from above, the edge is seen to pr
succession of tooth-like projections (fig. 399, *Cr*), which give it a
aspect. These projections are continued as flattened eminences
distance on the upper surface of the limbus, which is, therefo
smooth, at least near the edge, but marked in this way with em
and intervening furrows. Nearer the line of origin of the memb
Reissner, it becomes smoother, and here, too, its epithelial c
which is directly continuous with that of the under surface of R
membrane, is evenly distributed ; whereas at the crest itself the e
cells are, in the adult, only found in the furrows : so that the to
prominences project between the rows of epithelium into the
canal. Immediately below the overhanging projections, the epi
again forms a layer which lines the spiral groove, and is co
externally with the specialized cells, presently to be described as
the organ of Corti.

The **basilar membrane** stretches, as before mentioned,
between the osseous lamina and the spiral ligament, and separ
canal of the cochlea from the scala tympani. It increases in
at first rapidly but afterwards more gradually, from the base
apex of the cochlea, while the breadth of the osseous spiral
diminishes. Thus in the first turn of the cochlea, this membra
about half of the breadth of the septum, meaning about 0.041 m

Fig. 399.

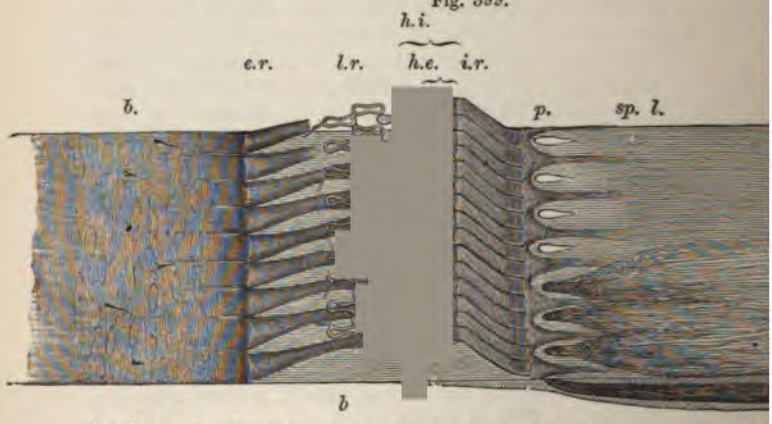


Fig. 399.—SEMI-DIAGRAMMATIC VIEW OF PART OF THE BASILAR MEMBRANE
OF CORTI OF THE RABBIT, FROM ABOVE AND THE SIDE. Much magnified.

l, limbus ; *Cr*, extremity or crest of limbus with tooth-like projections ;
membrane ; *sp.l*, spiral lamina with, *p*, perforations for transmission of
In the lower half of the part of the spiral lamina here represented the ner
left, and are supposed to be seen through the upper layer of that lamina, co
three of the perforations ; below, in the section of the lamina, they are show
a canal, or cleft, in the osseous substance ; *i.r*, fifteen of the inner rod
h.i, their flattened heads seen from above ; *e.r*, nine outer rods of Corti
heads, with the phalangeal processes extending outward from them and fo
the two rows of phalanges, the lamina reticularis, *l.r*. On the left of the figu
nective tissue fibres and nuclei of the undermost layer of the basilar me
seen through the upper layers. Portions of the basilar processes of the oute
remain attached here and there to the membrane at this part.

ds the apex of the cochlea, the proportion between the two parts is ged, until, near the helicotrema, the membranous part is left almost ported by any plate of bone, measuring as much as 0·495 mm., or twelve times as much as at the base (Hensen). The exact nature of sue composing the proper substance of the membrane is unknown, is probably analogous to that composing the rods of Corti, to be ards described. It is somewhat stiff in consistence, and may y be broken up into straight fibres which have a radial direction, ponding with a striation which the membrane, especially its outer presents when viewed on the surface (fig. 399). Externally at its ment to the spiral ligament, it breaks up into diverging fibres, spread into that projection. On the upper surface of the mem- is the epithelium which forms the organ of Corti, and the single of cells which is continued from this externally (fig. 400): on the surface it is covered by a layer of connective tissue (often de- d as part of the membrane), the fibres of which have a direction lel with the spiral, and across that of the fibres of the membrane er. There are numerous intermixed spindle-shaped corpuscles in tissue, which is in continuity with the lining periosteum of the tympani (fig. 399). Small blood-vessels are found in it, but rule extending only over the inner part of the membrane. They nally terminated by a rather larger longitudinally running vessel, ted opposite the outer rods of Corti, and known as the *vas spirale*.

he membrane of Reissner (figs. 398, 400, *R*), separates the scala ibuli from the canal of the cochlea. It is composed of an exceedingly ate layer of connective tissue continuous with the lining periosteum e scala vestibuli, and is covered on the surface which is turned to ochlear canal with a simple pavement epithelium which is in con- y below with the epithelium of the limbus and above with that the outer wall of the canal (fig. 400). The cells have each a r flattened nucleus, and not unfrequently contain fat droplets. estibular side of the membrane of Reissner is quite smooth, and is d with an epithelioid layer of flattened connective-tissue cells, guishable from the epithelial cells on the other side by their r delicacy of outline, and their larger size. A few blood-capil- are continued into the membrane from the neighbouring steum.

ter wall of the cochlear canal.—The periosteum which lines cala vestibuli and scala tympani, consists of ordinary connective e. There is no continuous lining of flattened cells on the free ce, such as covers the surface of serous membranes. On the r hand the periosteum which bounds the canal of the cochlea nally, is much thickened by a development of retiform connective e, and is covered by the epithelium of that tube, which here forms a e layer of cubical or columnar cells, many of which contain pigment. e is usually a slight inward projection a little above the spiral liga- , containing a prominent blood-vessel (fig. 400, *L. sp. a*). In the between this prominence and the membrane of Reissner, the sub- e of the periosteum is also frequently pigmented, and from con- ng large and numerous blood-vessels, the capillary loops of which even project between the bases of the epithelium-cells, is termed *vascularis* (*St. v.*). Immediately beneath the epithelium of the wall is a basement membrane, through which, in section, cell-

processes may here and there be seen passing into the epithelium of the subjacent connective tissue.

The **spiral ligament** (fig. 400, *Lsp*) appears in section as an angular prominence attached to the outer wall of the cochlea, with the basilar membrane prolonged from its apex. It is composed of a fibrous connective tissue, many of the cells of which have an elongated form and radiate from the point of attachment of the basilar membrane. They have been considered by some to be muscular, but there is no distinct proof of their contractile nature.

Fig. 400.

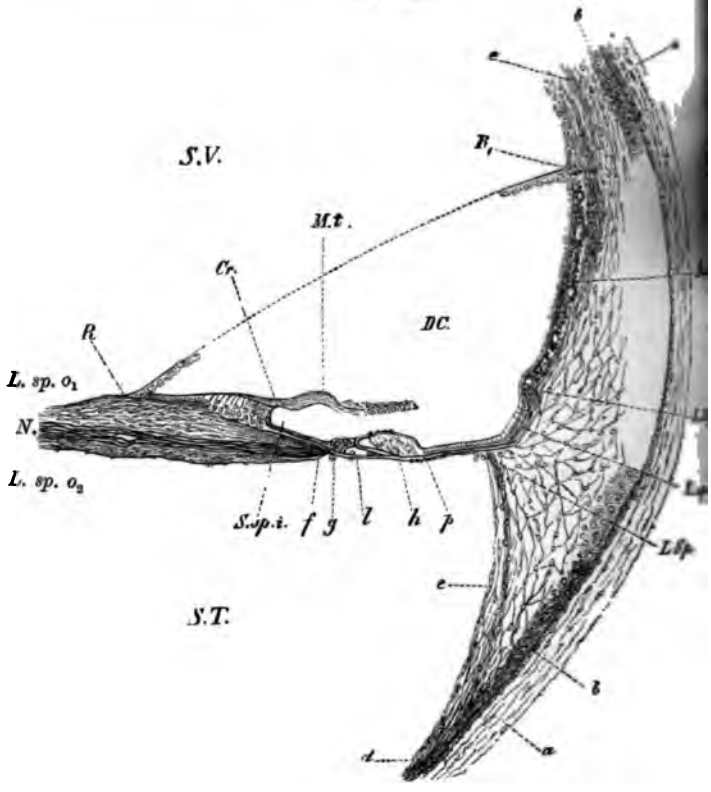
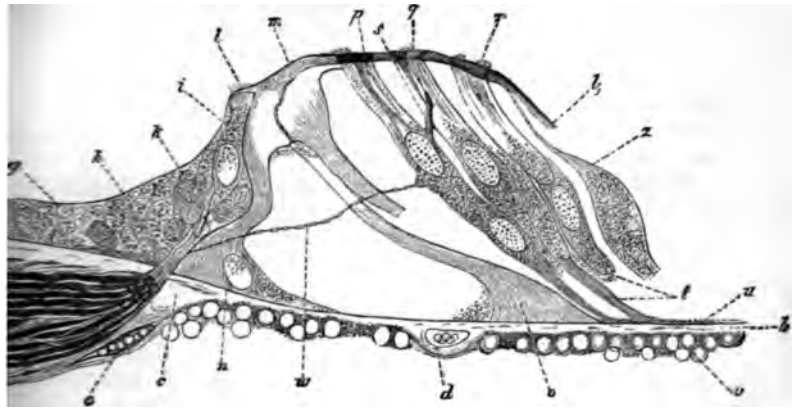


Fig. 400.—VERTICAL SECTION OF THE FIRST TURN OF THE COCHLEA OF A CH YEAR AND A HALF OLD. 100 DIAMETERS (Waldeyer).

SV, scala vestibuli; *ST*, scala tympani; *DC*, duct or canal of the cochlea; *L.sp.o*$_2$, vestibular and tympanal layer of the osseous spiral lamina with the sh nerve-fibres, *N*, between; *a*, *a*, outer bony wall of the cochlea; *b*, *b*, and *d*, peri *e*, *e*, connective tissue thickening forming at *L.Sp.* the spiral ligament; *S.* vascularis; *L.Sp.a*, prominence known as the *accessory spiral ligament*, spirally running blood-vessel, the *vas prominens*; *S.sp.i.*, spiral groove (inner); so-called *external spiral groove*; *R*, *R*$_1$, section of Reissner's membrane, the indicated only by a dotted line; from *R* to *Cr.*, limbus laminæ spiralis; *M.t.*, tectoria, somewhat raised up from its natural position; *f*—*p*, organ of Corti; turning up to enter epithelium; *g*, inner hair-cell region; *h*, region of the cells; *l*, basilar membrane underneath rods of Corti.

OF CORTI.—The epithelium which covers the basilar membrane requires a careful description, including as it does the highly-developed structures which are known by the name of the **organ of Corti**. The central part of this apparatus is formed by two sets of stiff, rod-like bodies—the inner and outer *rods of Corti* (figs. 401, 402)—

Fig. 401.



401.—SECTION OF THE ORGAN OF CORTI OF THE DOG (from Waldeyer). $\frac{300}{1}$.

end of spiral lamina; *b*, *c*, middle (homogeneous) layer of the basilar membrane; basilar (striated) layer; *v*, tympanal (connective tissue) layer; *d*, blood-vessel; in spiral lamina; *g*, epithelium of spiral groove; *h*, nerve-fibres passing towards hair-cells, *i*, *k*; *l*, auditory hairlets on inner hair-cells; *l*, *l'*, lamina reticularis; of the rods of Corti, jointed together; the inner rod is seen in its whole length; one is broken off half way, and the next one comes into view; *n*, cell at base of ; *p*, *q*, *r*, outer hair-cells; *s*, a cuticular process extending upwards, and pro-belonging to a cell of Deiters; *t*, lower ends of hair cells; two of them are attached lular processes to the basilar membrane; *w*, a nerve-fibril passing into an outer ll; *z*, a sustentacular cell of Deiters.

stand upon the basilar membrane, the outer series (*e.r.*), at some distance from the inner (*i.r.*), and are inclined towards each other, g in contact above. In this way each pair of rods forms a pointed with slanting sides (fig. 402), and since the rods of each series are

Fig. 402.

Fig. 402.—A PAIR OF RODS OF CORTI, FROM THE RABBIT'S COCHLEA, IN SIDE VIEW. (E. A. S.) HIGHLY MAGNIFIED.

b, *b*, basilar membrane; *i.r*, inner rod; *e.r*, outer rod. The nucleated protoplasmic masses at the feet are also shown.

eral juxtaposition, the double row of inclined columns forms a l (fig. 399) along the whole extent of the cochlear canal.

the inner side of the inner series of rods is a row of epithelial cells 401, *i*), which are surmounted by a brush of fine, short, stiff hairlets, sternal to the outer rods are three or four successive rows of similar

but more elongated cells (*p*, *q*, *r*). These cells are termed re
the *inner* and *outer hair-cells*. The hairlets of the outer hair-c
ject through apertures in a curiously formed cuticular membran
the *reticular lamina* (399, *l. r.*), which covers this part of the
Corti like a wire net. On either side of the two sets of hair-
epithelium, becoming gradually shorter, passes continuously
simple layer of cubical cells which is found in the spiral groov
the lateral part of the basilar membrane.

The whole organ is further covered by a thick, fibrillated m
—the *tectorial membrane* (fig. 400, *M.t.*)—which is attached at
to the upper surface of the limbus, falls over the crest, and rest
rods of Corti and the hair-cells, thus converting the spiral groo
a canal. It will be necessary to describe more minutely these
parts of the organ of Corti.

Rods of Corti.—The inner and outer rods of Corti differ fr
another in shape, although agreeing, for the most part, as regar
details of their structure. Each inner rod may be best compa
shape to a human ulna, the upper end of the rod being pretty acc

Fig. 403.

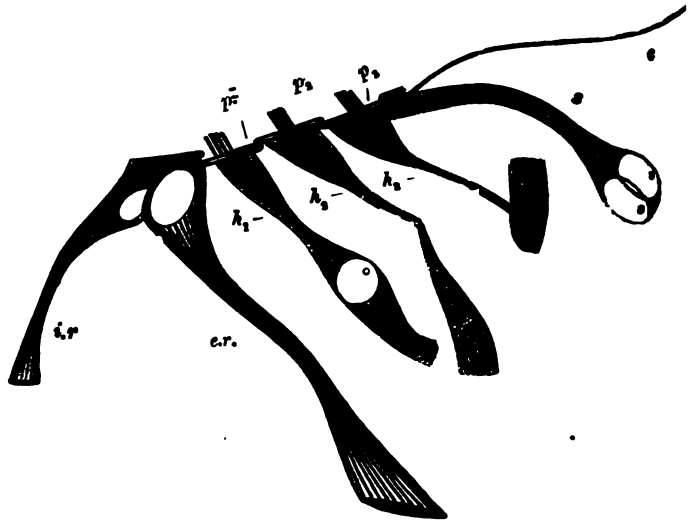


Fig. 403.—PROFILE VIEW OF AN INNER AND AN OUTER ROD IN CONNEXION THREE HAIR-CELLS, AND PART OF THE LAMINA RETICULARIS (FROM THE IG). (E.A.S.) VERY HIGHLY MAGNIFIED.

i.r, inner rod; *e.r*, outer rod; h_1, h_2, h_3, hair-cells of first, second, and t respectively. They appear, especially the second and third, narrow in the middl edge of the riband-shaped cell being here seen, but below have become accidenta so that the flattened side is brought into view. A nucleus is visible in h_1, but not h_2, h_3, probably owing to its being contained in the part of the cell the edge o turned towards the observer. The lower ends of all three, together with th processes, have become broken off in the preparation of the specimen; *s*, one ceeding epithelial cells; *c*, cuticular thread attached to lamina reticularis, an belonging to a cell of Deiters; *p*, phalangeal process of outer rod; p_1, p_2, p lamina reticularis seen in section.

nted by the upper extremity of that bone, the shape of the ole- and coronoid processes, as well as the concave articular surface n, being readily recognisable. The upper end of one of the outer n the other hand, somewhat resembles the outline of a swan's the rounded part, which represents the back of the head, fitting e concave surface on the head of the corresponding inner rod or hile the part which represents the bill projects outwards and is ted with the reticular lamina, aiding to form the first series of or the transmission of the auditory hairlets. Both inner and ods are more slender about the middle of their length and expand below, so as to rest upon the basilar membrane by a somewhat d foot. They are distinctly striated throughout their length 3), and the striation or fibrillation passes into that of the basilar ane, to which they are thus intimately connected (fig. 399). especially well seen in the outer rods.

e head of the outer rod is an oval part free from fibres, and staining with more deeply than the remainder of the rod: this may represent the of an epithelial cell from which the rod was originally developed. A but smaller clear body, staining deeply with carmine, is sometimes to be the head of the inner rod, and the substance of the rod in its neighbour- as a somewhat granular appearance (fig. 403).

connection with both inner and outer rods, there is seen a proto- ic cell occupying the angle which the rod makes with the plane of asilar membrane (fig. 402). Sometimes these cells extend along the rane until they come into contact.

e inner rods are more numerous than the outer;* they are also more y set and touch one another along their whole length, whereas the r rods are only in contact laterally by their heads; finally the outer are in all parts longer than the inner, and in the upper turns of the lea considerably so.

w the two sets of rods are jointed together is not very clear. It is certain the individual rods have little, if any, independent movement; they are rely fixed below to the basilar membrane, and the heads of adjacent rods are lose contact.

Hair-cells.—The *inner hair-cells* are closely applied against two three of the corresponding rods, the cells being considerably larger diameter than the rods. They are very like somewhat short, umnar epithelium-cells, and are prolonged below into a process, or it r be more than one, which, according to Waldeyer, is directly connected ne of the nerve fibres which turn up through the spiral lamina just w these cells (fig. 401). Beneath them, and extending also under gradually decreasing columnar epithelium of the spiral groove, is a r of protoplasmic cells with large round nuclei, amongst which fine re-fibres are said to run in a radial direction. Around the top of each r hair-cell is a sort of ring of cuticular substance, which is connected slight projections on the flattened heads of the inner rods, and ars to represent the reticular lamina in this place.

he *outer hair-cells* are peculiar in shape. They are cylindrical at upper end, where they fit into the rings of the reticular lamina and

According to Waldeyer there are altogether in the human cochlea about 6000 of the rods and 4500 of the outer ones.

bear the hairlets, but lower down they are flattened from within out[illegible] that, in profile, they look narrow, but broader when seen on the [illegible] (fig. 403). These cells end below with a rounded extremity (fig. 404, [illegible] slightly bulged to one side, whilst from the other side a thin cutic[illegible]

Fig. 404.

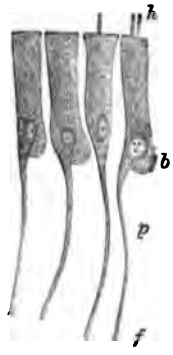


Fig. 404.—Four outer hair-cells in connection with [illegible] basilar processes. From the guinea-pig. Highly [illegible] nified. (E. A. S.)

The cells belong to the same series and are viewed flat. [illegible] one or two hairlets which have remained attached; *b*, [illegible] lower end of cell; *p*, basilar process, protoplasmic above [illegible] becoming cuticular below and slightly expanded at the extr[illegible] *f*, which is broken away from the basilar membrane.

process (*p*) is prolonged which is fixed to the ba[illegible] membrane (basilar process). Beneath the hair-c[illegible] and resting by a broad base upon the basilar m[illegible] brane, certain other cells are found which are kn[illegible] as the *cells of Deiters* (fig. 401, *z*). These ex[illegible] upwards for a certain distance between the lo[illegible] ends of the hair-cells, and each one is then prolon[illegible] towards the surface by a fine cuticular process, wh[illegible] is attached above to one of the so-called phalanges of the retic[illegible] lamina, and is known as the phalangeal process.

Hensen describes a clear oval capsule with a spiral fibre wound around it, o[illegible] cupying the part of the cell next to the free extremity.

According to Waldeyer the outer hair-cells and the cells of Deiters are, in t[illegible] dog and some other animals, conjoined to form double cells with two nuclei.

Fig. 405.

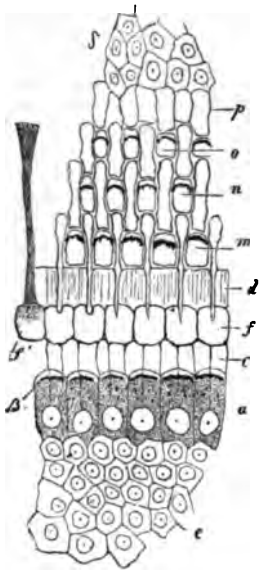


Fig. 405.—Sketch from below of lamina reticu[illegible] laris and adjoining structures from the cat. Highly magnified (Kölliker).

a, inner hair-cells with hairlets, *β*; *c*, epithelium of spiral groove; *e*, inner rods; *d*, part of heads of inner rods overlapping those of the outer rods; *f*, heads of outer rods: their long phalangeal processes are seen, but the rods themselves are not represented, except at *f'*; *m*, *n*, *o*, rings of lamina reticularis with semicircles of hairlets, the hair-cells not being represented; *p*, cuticular tissue between external epithelial cells, *s*.

In most animals there are three series of outer hair-cells, but in man there are four series (fig. 400, *h*) and even five and six in the upper turns of the cochlea (Pritchard). The columnar cells outside the hair-cells are much elongated and obliquely disposed, but become gradually shorter and more vertical as they pass into the simple cubical epithelium on the outer part of the basilar membrane.

Lamina reticularis (figs. 399, 405).—The net-like membrane which overlies the outer hair-cell region of the organ of Corti is composed of at least two rows of elongated fiddle-shaped structures termed "phalanges" which are united to one another and to the phalangeal processes of the outer rods in such a manner as to leave between them oblong apertures

ugh which the free ends of the hair-cells with their semicircular rows ditory hairs project. The phalanges, although they seem like rings, reality thin plates with thickened margins, and are to all appear- of a cuticular nature: the most external row of phalanges is in con- ty with a cuticular tissue which lies between the external epithelium (fig. 405, *p*). Attached to the phalanges below are the phalangeal esses of the cells of Deiters. The lamina varies in extent with the ber of rows of hair-cells. Where there are four or more of these, a sponding increase in the number of rows of phalanges is observed. phalanges serve to isolate the hair-bearing ends of the auditory cells.

The tectorial membrane is the last special structure which remains be described in connection with the organ of Corti. It arises, as re stated, on the limbus, not far from the line of origin of Reissner's brane. It overlies the projecting teeth at the edge of the limbus, also the epithelium between them: all this part of the mem- e is thin and delicate, imperceptibly shading off towards the inner of attachment. As the membrane projects over the crest of the , it swells out below into a pad-like projection which covers d partly fills up the spiral groove, and rests below upon the rods of i and contiguous structures. Towards its external edge the mem- e again thins out, and over-lies the outer hair-cell region as a delicate presenting a somewhat reticular appearance, as if impressed by or ded on the subjacent structures. The thickened part of the mbrane is distinctly fibrous in appearance (the fibrillation extending within out), and after immersion in weak solutions of chromic acid, bichromate of potash, it appears to possess considerable toughness and ticity. From its position the hairlets borne by the hair-cells must essarily be in contact with the under surface of this membrane. bout its origin nothing certain is known, but it appears to be formed a cuticular deposit or secretion from the epithelial cells, upon which, n at a comparatively early stage of development, it may be seen to lie. the position which it bears relative to the auditory epithelium it responds to the cupulæ terminales of the cristæ acusticæ and to the olithic accumulations of the maculæ.

Nerves of the cochlea.—The branch of the auditory nerve which s to the cochlea is given off in common with those to the saccule and posterior ampulla. It is shorter, flatter, and broader than any of the er branches. It perforates the bone by groups of minute foramina at bottom of the internal meatus, below the opening of the Fallopian educt. These groups are arranged in a shallow spiral furrow (tractus ralis foraminulentus) in the centre of the base of the cochlea; and y lead into small bony canals, which first follow the direction of the s of the cochlea, through the modiolus, and then radiate outwards, ween the plates of the bony spiral lamina. In the centre of the ral tract is a larger foramen which leads to the central canal of the diolus. Through this foramen and canal the filaments for the last f-turn of the spiral lamina are conducted; whilst the first two turns supplied by the filaments which occupy the smaller foramina and t canals. Near the root of the spiral lamina the nerve-fibres pass wards through a spirally wound ganglionic cord, (*ganglion spirale*) ated in the special bony canal (*spiral canal of the modiolus*) already tioned. The cells of this ganglion are bipolar and each nerve-fibre pears to have one of the cells interpolated in its course. From the outer

side of the ganglion, the fibres, having resumed their medullary
pass onwards with a plexiform arrangement, at first in distinct bu

Fig. 406.

Fig. 406. — GENERAL VIEW OF THE MODE OF DISTRIBUTION OF THE COCHLEA
ALL THE OTHER PARTS HAVING BEEN REMOVED.

mosing cords (fig. 407, B, 3), contained in separate canals in t
lamina, but afterwards spreading out into a stratum of interm
fibres, to be again gathered up, near the edge of the osseous lami

Fig. 407.

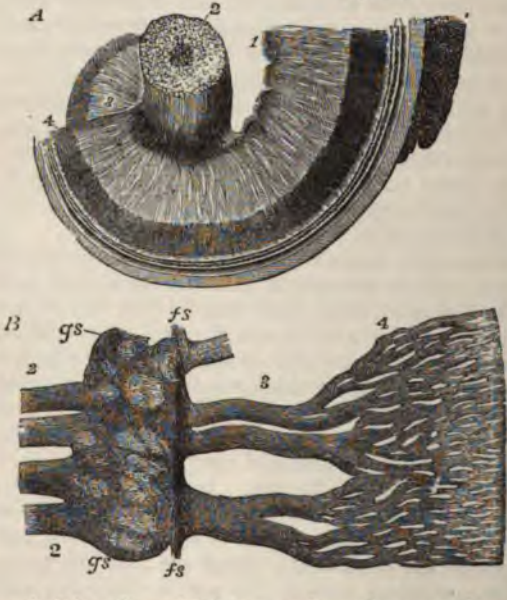


Fig. 407.—DISTRI
THE COCHLEAR
THE SPIRAL LAM
Henle).

A, part of the
and spiral lamina
from the base, sh
plexiform arrang
the cochlear nerve
ments of the ner
from the tractus sp
minulentus; 2, b
the nerve enterin
tral canal of the
3, wide plexus in
lamina spiralis;
plexus at its b
part of the nerve
and more highly
2, twigs of the
the modiolus cl
lamina spiralis
spiral ganglion;
fibres running sp
the outer part
glionic swelling
plexus; 4, close
nerve-fibres as in

conical bundles which turn abruptly upwards, and passing thr
elongated apertures previously described (p. 457 and fig. 399,
the epithelium in the region of the inner hair-cells (fig. 401, *h*).

Little is known positively with regard to the actual mode of endi
nerves amongst these structures. As they pass through the apertur

[illegible]ne, they lose their medullary sheath and dark borders, and are continued [illegible]e axis-cylinders. Their further course is still a matter of doubt. Some [illegible] are stated by Waldeyer to pass directly into the lower ends of the inner [illegible]-cells, and others to pass outwards between the rods of Corti, stretching [illegible] the tunnel which these enclose, and eventually ending in the outer hair-[illegible]; but these statements, although not improbable, yet require confirmation.

[illegible]essels of the cochlea.—The branches of the internal auditory artery to the [illegible]lea, twelve or fourteen in number, arising at the bottom of the internal [illegible]tory meatus, traverse small canals in the modiolus and bony lamina spiralis, [illegible] form in the latter a capillary plexus that joins at intervals the vas spirale, [illegible]iously mentioned. From this plexus offsets are distributed in the form of a [illegible]-network on the periosteum, but the vessels do not anastomose across the [illegible]mbrana basilaris. The cochlea also receives through the fenestra rotunda a [illegible] from the stylomastoid branch of the occipital artery.

[illegible]he veins of the cochlea issue from the grooves of the cochlear axis, and join [illegible]e veins of the vestibule and semicircular canals at the base of the modiolus. A [illegible]ll sinus-like vein passes through the aqueductus cochleæ, from the lowermost [illegible]n of the cochlear tube, and joins the commencement of the internal jugular [illegible].

[illegible]easurements of some of the parts of the cochlea.—The following numbers [illegible] the average dimensions of various parts of the human cochlea. They are [illegible]d from Waldeyer (article "Cochlea" in Stricker's Handbook), and represent [illegible]ise in micromillimeters.*

Cochlear canal, breadth, 1st turn	800 μ
„ „ „ 2nd turn	700
„ „, extreme height	500
Reissner's membrane, breadth, 1st turn	900
„ „ „ 2nd turn	700
Limbus laminæ spiralis, breadth, 1st turn	300
„ „ „ 2nd turn	200—250
Rods of Corti, space between attachment of feet	66—70
„ „ height of arch	12
„ „ length of inner rods	50
„ „ length of outer rods	60—66
Hair-cells, length of inner	18
„ „ length of outer, with basilar process	48
„ „ length of hairlets	4
Membrana tectoria, extreme breadth	200—230
„ „ extreme thickness	50

Recent Literature of the Ear.—On the external ear:—*Kessel*, in Stricker's [illegible]dbook, 1872; *v. Troeltsch*, Handb. d. Ohrenheilk., 1881.

On the tympanic cavity and ossicles:—*Kessel*, in Stricker's Handbook, 1872, and [illegible]ch. f. Ohrenheilk., 1874 (action of muscles); *Rüdinger*, in Monatschr. f. Ohrenheilk., [illegible]872; and "Beiträge &c.," 1873; *Weber* in Monatschr. f. Ohrenh., 1872 (tensor tym-[illegible]ni); *Brunner*, in Knapp u. Moos' Arch., 1873 (articulations of ossicles); *Urbantschitsch*, [illegible] Arch. f. Ohrenheilk., 1873 and 1876; *Politzer*, in same journal, 1875 and 1876 [illegible]uscles, and vessels); *Moldenhauer*, in same journal, 1876, and Vergleichende [illegible]istol. d. Trommelfells, Arch. f. Ohrenheilk., 1878; *Moos*, in Knapp u. Moos' Arch., [illegible]877 (vessels of membrane); *Körner*, in Monatschr. f. Ohrenheilk., 1878; *Hensen*, Article "Gehör," in Hermann's Handb., 1880.

On the Eustachian tube:—*Mach u. Kessel*, in Wiener Sitzungsb., 1872; *Weber-Liel*, "Ueber das Wesen, &c.," Berlin, 1878; *Moos*, Wiesbaden, 1874; *Zuckerkandl*, in [illegible]Monatschr. f. Ohrenheilk., 1874; *Yule*, in Journ. of Anat. and Physiol., 1874; *Urbanschitsch*, in Arch. f. Ohrenheilk., 1875; and Wiener med. Jahrb., 1875; *Zaufal; Michel*, in Arch. f. Ohrenheilk., 1875 and 1876; *Lucæ*, in Virch. Arch., 1875 and 1878; *Gerlach*, in Erlangen Sitzungsb., 1875.

On the membranous labyrinth:—*Rüdinger*, in Stricker's Handb., 1872; *G. Retzius*, Anat. Unters. 1872; "Morphologie des Gehörlabyrinths," Stockholm, 1881; and "Biologische Studien," 1882; *v. Ebner*, Epith. d. crista acust., Schriften d. med. Ver

* A micromillimeter is the $\frac{1}{1000}$th part of a millimeter, or the $\frac{1}{25000}$th part of an inch, and is generally represented by the Greek letter μ.

zu Innsbrück, 1872; *Hasse*, Anat. Studien, 1872; and Vergleichende Morphol. 1873; *Urban Pritchard*, Nerves of Vest. and Semic. Canals, Quarterly Journal of Science, 1876; *P. Meyer*, Étude histologique, &c., 1876; *Weber-Liel* in Med. Centralbl., 1876, and Monatschr. f. Ohrenh., 1876 (fenestra rotunda).

On the aqueductus vestibuli and saccus endolymphaticus:—*Key and Retzius*, in Studien ü. d. Nervensystem, &c., 1874; *Zuckerkandl*, in Monatschr. f. Ohrenheilk., 1876; *Weber-Liel*, in Centralbl. f. d. med. Wissensch., 1876, and Monatschr. f. Ohrenheilk., 1877; *Rüdinger*, in Zeitschr. f. Anat. u. Entw., 1876.

On the cochlea:—*Waldeyer*, in Stricker's Handb., 1872; *Gottstein*, in Arch. f. mikr. Anat., 1872; *Urban Pritchard*, in Proc. Roy. Soc., 1872, and 1876; *Böttcher*, in Deutsch. med. Zeitschr., 1873; *Hensen*, in Arch. f. Ohrenheilk., 1873 and 1874; *Lavdowsky*, Arch. f. mikr. Anat., XIII.; *Nuel*, Mem. cour., Bruxelles, 1878.

THE NOSE.

The nose is the special organ of the sense of smell. It has also other functions to fulfil;—for, communicating freely with the cavities of the mouth and lungs, it is concerned in respiration, voice, and taste; and by means of its muscles it assists in expression.

Fig. 408. Fig. 409. Fig. 410.

Fig. 408.—Lateral view of the cartilages of the nose (Arnold). ½

a, right nasal bone; *b*, nasal process of the superior maxillary bone; 1, upper lateral cartilage; 2, lower lateral cartilage; 2*, inner part of the same; 3, sesamoid cartilage, here distinct, but generally united with the lower lateral cartilage.

Fig. 409.—Front view of the cartilages of the nose (Arnold). ½

a, *a'*, nasal bones; 1, 1', upper lateral cartilages; 2, 2', lower lateral cartilages.

Fig. 410.—View of the cartilages of the nose from below (Arnold). ½

2, 2', outer part of the lower lateral cartilages; 2*, 2*, inner part of the same; 4, lower edge of the cartilage of the septum.

The nose consists of the anterior prominent part, composed of bone and cartilages, with muscles (already described in Vol. I.), and with two orifices, *anterior nares*, opening downwards; and of the two nasal fossæ, in the upper parts of which the olfactory nerves are expanded. The nasal fossæ are separated from each other by a partition, *septum nasi*, formed of bone and cartilage in the greater part of its extent, but longed between the anterior nares only by a thick fold of integu termed the membranous septum or *columna nasi*. The nasal fosse communicate with hollows in the neighbouring bones (ethmoid, sphen frontal, and superior maxillary); and they open backwards into

ix through the *posterior nares*. The skin of the nose is studded, larly in the grooves of the alæ or outer walls of the nostrils, with ous small openings, which lead to sebaceous follicles. Within the ı of the nostrils there is a number of short, stiff, and slightly hairs—*vibrissæ*—which grow from the inner surface of the alæ ptum nasi.

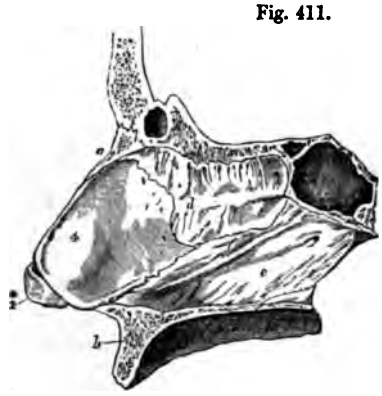
CARTILAGES OF THE NOSE.

e are the chief support of the outer part of the organ. They the triangular interval seen in front of the nasal cavity in the kull (anterior nasal aperture), and assist in forming the septum ı the nasal fossæ. There are two large cartilages on each side, e mesial cartilage of the septum.

upper lateral cartilages (figs. 408 and 409, 1) are situated in the part of the projecting portion of the nose, immediately below the argin of the nasal bones. Each is flattened and triangular in and presents one surface outwards, and the other inwards towards al cavity. The anterior margin, thicker than the posterior, meets eral cartilage of the opposite side above, but is united with the f the cartilage of the septum below; indeed, by some anatomists, ıle, the upper lateral are described with the median cartilage, of they may be regarded as reflected wings. The inferior margin is ted by fibrous membrane with the lower lateral cartilage; and the or edge is closely attached to the free margins of the upper maxilla the nasal bone.

lower lateral cartilages (cartilages of the aperture) (2, 2′, in the re thinner than the preceding, below which they are placed, and ly characterised by their peculiar curved form. Each consists of

Fig. 411.



L.—Osseous and cartilaginous septum of the nose, seen the left side (Arnold). ⅔

ght nasal bone; *b*, superior ry bone; *c*, sphenoidal sinus; endicular plate of the eth- ne; *e*, vomer; 2*, inner part ght lower lateral cartilage; 4, e of the septum.

ongated plate, so bent itself as to pass in front ı each side of the nostril ich it belongs, and by rangement serve to keep ı. The outer portion is hat oval and flattened, gularly convex externally. Behind, it is attacned to the margin of pper maxilla by tough fibrous membrane, enclosed in which is usually to be met with either a prolongation backwards of sterior angle of the cartilage, or two or three separate cartilaginous s (*cartilag. minores vel sesamoideæ*) (fig. 408, 3); above, it is also by fibrous membrane, to the upper lateral cartilage, and to wer and fore part of the cartilage of the septum. Towards iddle line it is curved backwards (fig. 409), bounding a deep

mesial grove, at the bottom of which it meets with its fellow opposite side, and continues to pass backwards, lying in the up of the columna nasi, below the level of the cartilage of the septum inner part of the cartilage of the ala is thick and narrow, ca wards, and ends in a free rounded margin (fig. 411, 2*), which outwards. The greater part of the ala of the nose, like the l the ear, is formed of thickened skin with subjacent tissue, and supported by cartilage.

The *cartilage of the septum* (fig. 411, 4) is quadrilateral in fo is thicker at the edges than near the centre. It is placed vertically in the middle line of the nose, and completes, at t part, the separation between the nasal fossæ. The anterior of the cartilage, thickest above, is firmly attached to the back nasal bones near their line of junction; and below this it li cessively between the upper and the lower lateral cartilages, unite mately with the former and loosely with the latter. The posterior is fixed to the lower and fore part of the central plate of the e bone (*e*); and the lower margin is received into the groove of the (*v*), as well as into the median ridge between the superior maxilla

This cartilage is the persistent anterior extremity of the prim cranium. In young subjects it is prolonged back to the body pre-sphenoid bone; and in many adults an irregular thin band re between the vomer and the central plate of the ethmoid.

NASAL FOSSÆ.

The nasal fossæ, and the various openings into them, with the terior nares, have been previously described as they exist in the ske

Fig. 412.

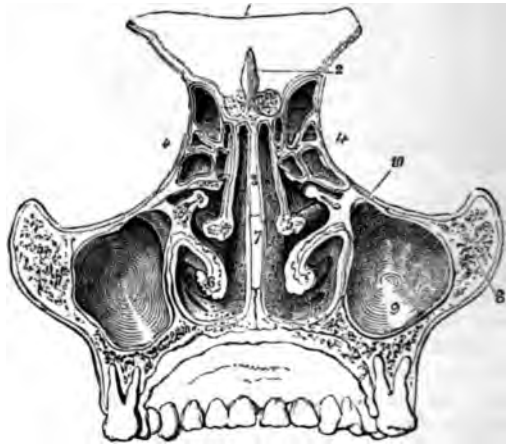


Fig. 412.—TRANSVERSE VERTICAL SECTION OF THE NASAL FOSSÆ SEEN FROM (Arnold). ¾

1, part of the frontal bone; 2, crista galli; 3, perpendicular plate of the between 4 and 4, the ethmoidal cells; 5, right middle spongy bone; 6, left low bone; 7, vomer; 8, malar bone; 9, maxillary sinus; 10, its opening into th meatus.

the greater part of that description is also applicable generally to ose in a recent state; but there are certain differences which d on the thickness of the lining membrane, which not only lines alls of the fossæ, but covers the spongy bones on both sides. Thus, first place, the nasal cavity is much narrower in the recent state. dly, in consequence of the prolongations of the membrane on their margins, the turbinate bones, and more particularly the lower pair, r to be both more prominent, and longer, than in the dried skull. dly, some of the foramina in the bones are narrowed, and others ed over by the lining membrane.

the individual parts of the nasal fossæ the following particulars are to be d.

the *upper meatus*, the small orifice which leads into the posterior ethmoidal is lined by a prolongation of the thin mucous membrane which is continued those cavities; but the spheno-palatine foramen is covered over and closed membrane.

the *middle meatus*, the aperture of the infundibulum is nearly hidden by verhanging fold of membrane: it leads directly into the anterior ethmoidal , and through them into the frontal sinus. Below and behind this, the ge into the antrum of Highmore is surrounded by a fold of the membrane metimes prominent and even slightly valvular), which leaves a circular ture much smaller than the foramen in the bony meatus.

the *lower meatus* the inferior orifice of the nasal duct is defended by one or folds of membrane; and when there are two, the folds are often adapted so rately together as to prevent air from passing back from the cavity of the to the lachrymal sac.

the *roof* the apertures in the cribriform plate of the ethmoid bone are con- ed by the membrane, but the openings into the sphenoidal sinuses receive olongation from it.

the *floor* the incisor foramen is in the recent state generally closed. Some- s, however, a narrow funnel-shaped tube of mucous membrane (naso- tine canal or canal of Stenson) passes obliquely downwards from each nasal for a short distance towards the front of the hard palate. Vesalius, Stenson, Santorini believed that these tubes of membrane opened generally into the of the mouth by small apertures close behind the central incisor teeth. ller, Scarpa, and Jacobson, found the canals in man usually closed, and often icult of detection.

Modern anatomists have also been divided in opinion on this matter, but it uld appear that the latter opinion (that of Haller and Scarpa) is correct. The nal is the remnant of the wide communication between the nasal and buccal vities found at an early period of fœtal life, being in man usually obliterated, least in its lower part, before birth, although persistent in many animals. It long represented below by a solid column of epithelium cells continuous with e epithelium of the palate, and above by a narrow tube lined with ciliated thelium, opening into the floor of the nasal fossa but closed below. (Lebouc, e canal nasopalatin chez l'homme, Archives de Biologie, 1881.)

MUCOUS MEMBRANE.

The pituitary or Schneiderian membrane, which lines the cavities of e nose, is a highly vascular mucous membrane, inseparably united with e periosteum and perichondrium over which it lies. It is continuous th the skin through the nostrils; with the mucous membrane of the rynx through the posterior nares; with the conjunctiva through the al duct and lachrymal canaliculi; and with the lining membrane of several sinuses which communicate with the nasal fossæ. The pitui- y membrane, however, varies much in thickness and vascularity in

different parts. It is thickest and most vascular over the turbi bones (particularly the inferior) and on the septum nasi it is also v thick and spongy; but in the intervals between the turbinate bones over the floor of the nasal fossæ, it is considerably thinner. In maxillary, frontal, and sphenoidal sinuses, and in the ethmoidal cells lining mucous membrane is very thin and pale, and contrasts strongly that which lines the nasal fossæ.

The character of the epithelium varies in different parts, and by in a general way, three regions of the nasal fossæ may be distinguish Thus, the region of the external nostrils (the vestibule), including the part which is roofed by the nasal cartilages, is lined with stratified squamous epithelium; and the remainder is divisible into two parts, viz.

Fig. 413.

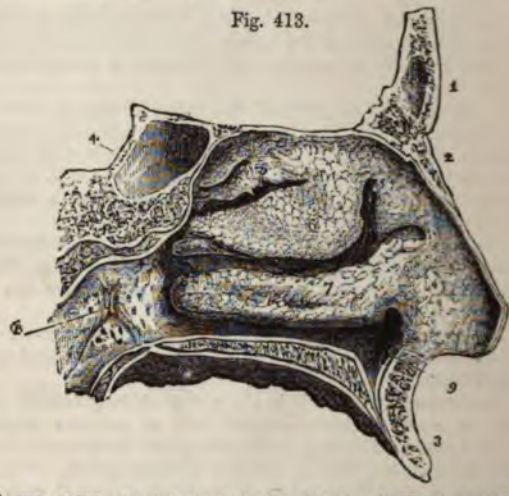


Fig. 413.—Outer wall of the left nasal fossa, covered by the pituitary membrane (Arnold). ¾

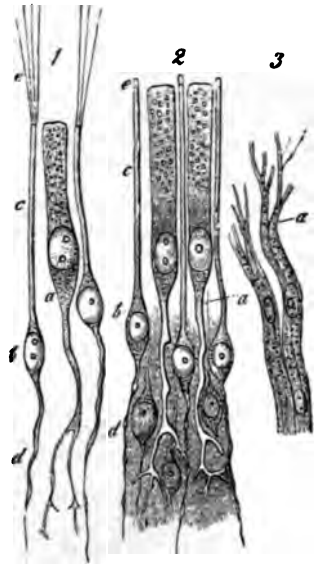
1, frontal bone; 2, left nasal bone; 3, superior maxillary; 4, body of the sphenoid with the sphenoidal sinus; 5, projection of the membrane covering the upper spongy bone; 6, that of the middle; 7, that of the lower; the upper, middle, and lower meatuses are seen below the corresponding spongy bones; 8, opening of the Eustachian tube; 9, depression of the lining membrane of the nose in the anterior palatine canal.

the upper or olfactory region in which the epithelium is non-ciliated and columnar, and the lower or respiratory region in which, as also in the sinuses, it is ciliated and columnar. The membrane in the respiratory part covers the inferior turbinate and all the lower portions of the fossæ, and is studded with numerous racemose glands (yielding in part mucus, in part a more watery secretion), which open by orifices apparent on the surface. They are most numerous about the middle and hinder parts of the nasal fossæ, and are largest at the back of the septum near the floor of the nasal cavity. Glands which are much smaller and less numerous open into the several cavities which communicate with the nasal fossæ. Besides the glands the membrane contains a variable amount of lymphoid tissue, occasionally accumulated into "nodules." In some parts large venous plexuses are found, encircled, as well as the alveoli of the glands amongst which they lie, by bundles of plain muscular fibres (Klein), thus forming a sort of cavernous tissue.

mucous membrane.—The olfactory region or that in actory nerve is distributed, includes the upper and middle ts of the fossæ, and the upper portion of the septum. It rascular, a close plexus of large capillary vessels being found ing membrane throughout its whole extent. Its mucous thicker and more delicate in consistence than that of the n, being soft and pulpy. It has a distinct yellow colour in in some animals. The glands of this region (glands of numerous, but are of a more simple structure than those part of the fossæ. They open by fine ducts lined with s which extend to the surface between the olfactory epi-

In the mucous membrane itself, the gland-tube is some- ited and enlarged, and it may have one or two branches.

Fig. 414.



ELLS AND TERMINAL NERVE- OLFACTORY REGION (from Frey Highly magnified.

og ; 2, from man ; *a*, epithelial leeply into a ramified process ; s ; *c*, their peripheral rods ; *e*, , seen in 1 to be prolonged into eir central filaments ; 3, olfac- from the dog ; *a*, the division

l throughout by a base- ne, and lined and almost columnar or polyhedral . Here and there ordinary nds are found ; where se the epithelium of the ding to Klein, is ciliated tory.

ar cells on the surface of mucous membrane (fig olonged at their deep ex a process which is gener- t thickened towards its d usually includes a num- granules ; and from this t branches proceed, which are stated by Exner and Martin te with those of neighbouring cells, so as to form a com- etwork throughout the extent of the membrane, underneath n. Amongst these branching central ends of the columnar re a large number of peculiar spindle-shaped cells (fig. consisting of a large, clear nucleus surrounded by a rela- mount of granular protoplasm. From each cell proceeds a d a deep process. The superficial process (*c*) is a cylindrical pering thread passing directly to the surface, and termi- tly at about the same level as the free surface of the epi- etween which it lies, or a little beyond ; the deep process (*d*) der, and passes vertically inwards. This last frequently ded appearance similar to that observed in fine nerve-fila- se cells were termed by Max Schultze, *olfactory cells*, to hem from the columnar epithelium-cells, which are much

fewer in number, and which are entirely surrounded with the fine hair-like peripheral processes of the smaller cells. It is probable that the varicose central processes of these cells are directly continuous with fibrils of the olfactory nerve, but the continuity has never been actually observed. The nucleated bodies of the olfactory cells are several deep, and form a layer of considerable thickness beneath the columnar cells.

Both the olfactory and the columnar cells project through apertures in a cuticular lamina which bounds the mucous membrane superficially (*external limiting membrane* of v. Brunn).

The peripheral process of the olfactory-cell was observed by Schultze to be surmounted by a short projection (fig. 414, 2, *e*), but this appearance may result from the coagulation of albuminous matter escaped from the interior of the process. Long and fine hair-like processes do, however, exist on the olfactory-cells of amphibia, reptiles, and birds (fig. 414, 1, *e*), but they have not been observed in mammals.

According to Exner there is no sharp distinction between columnar and olfactory-cells, but intermediate forms are to be met with, and the olfactory cells are, in fact, only a less developed condition of the columnar cells. He states that both kinds are connected with the olfactory nerve-fibres, that in the lower vertebrata they may both bear hair-like processes, and that in the frog after removal of the olfactory lobes, they both disappear and give place to ordinary ciliated cells.

In the rabbit and guinea-pig Klein, in confirmation of a statement by Schultze, describes a lowermost layer of conical cells resting by their bases vertically upon the basement membrane.

Fig. 415.

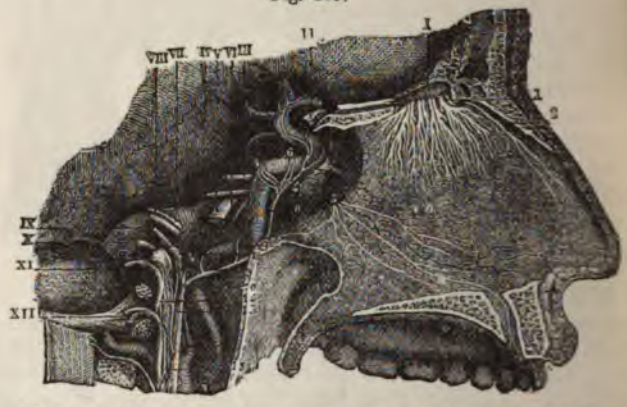


Fig. 415.—NERVES OF THE SEPTUM NASI, SEEN FROM THE RIGHT SIDE (from Sa after Hirschfeld and Leveillé). $\frac{2}{3}$

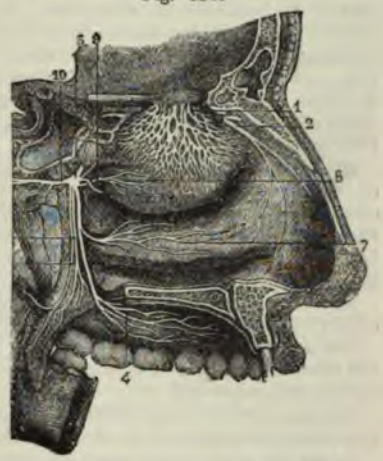
I, the olfactory bulb; 1, the olfactory nerves passing through the foramina of cribriform plate, and descending to be distributed on the septum; 2, the inter septal twig of the nasal branch of the ophthalmic nerve; 3, naso-palatine nerves.

Olfactory Nerve.—The filaments of this nerve, lodged at first grooves on the surface of the bones, enter the substance of Schneiderian membrane obliquely. The nerves of the septum (fig. are rather larger than those of the outer wall of the nasal fossæ; extend over the upper third of the septum, becoming very indis as they descend. The nerves of the outer wall are divided into

e posterior being distributed over the surface of the upper one, and the anterior over the plain surface of the ethmoid ddle turbinate bone.

es ramify so as to form flattened tufts, the filaments of which, ut laterally and communicating freely with similar offsets on orm a close plexus, with elongated and narrow meshes.

Fig. 416.



ERVES OF THE OUTER WALL SAL FOSSÆ (from Sappey, feld and Leveillé). $\frac{3}{5}$

of the branches of the , descending upon the region or and middle turbinated ernal twig of the ethmoidal nasal nerve; 3, spheno- ion; 4, ramification of the ine nerves; 5, posterior, divisions of the palatine anch to the region of the ated bone; 8, branch to the superior and middle es; 9, naso-palatine branch cut short.

structure the olfac- ibres differ much from y dark-bordered fibres ral and spinal nerves: no medullary sheath, -cylinders provided with a distinct nucleated sheath, much ct than that of the fibres of Remak and with nuclei at less tervals (fig. 417).

Fig. 417.

ERVE-FIBRES FROM THE OLFACTORY MUCOUS MEMBRANE (Max Schultze).

Magnified between 400 and 500 diameters.

of the olfactory nerve of the sheep; at *a*, *a*, two dark bordered or medul- ibres, from the fifth pair, associated with the pale olfactory fibres.

ter part of the mucous membrane of the nasal fossæ is pro- ith nerves of common sensibility, derived from branches of the the distribution of these has already been described in Vol. I.

of Jacobson.—In the anterior and lower part of the nasal septum ure may be seen opening obliquely on to the surface of the mu- ne slightly above and in front of the orifice of the Stenonian canal. leads into a minute canal which passes backwards for a short dis- he septum to terminate blindly a few millimeters from the orifice. hich is lined with epithelium continuous with that of the nasal as numerous glands opening into it, is the homologue of a much

of the olfactory nerve, and in these animals is no doubt of high fun portance as an accessory to the proper organ of smell. For a further this curious structure as well as references to the literature of the s Kölliker, Ueber die Jacobson-schen Organe des Menschen, Leipzig, 18 series of papers by Klein in the Quarterly Journal of Microscopical S 1881 and 1882.

Blood-vessels and lymphatics of the nasal fossæ. The *spheno-pala of the internal maxillary artery* enters the cavity by the spheno-palatin and divides into external branches to the meatuses and inner surface binate bones, sending offsets also to the ethmoidal cells and to the ma frontal sinuses, and an internal branch (naso-palatine) along the sep incisor foramen.

The *descending palatine branch of the internal maxillary artery* g offsets to the hinder part of the inferior turbinate bone and meatus.

The *anterior ethmoidal branch of the ophthalmic artery* enters the c the nasal nerve and is distributed to the mucous membrane of the fore septum and outer wall.

The *posterior ethmoidal branch* of the same artery sends small twi posterior ethmoidal cells, to the roof, and to the upper part of the septu

Lastly the *artery of the septum* (from the superior coronary of the f plies the part near the anterior nares. The several arteries anastom together in the mucous membrane.

The *veins* form a dense plexus in the mucous membrane, and th largely developed over the lower turbinate bone, and on the lower a part of the septum. The trunks leaving the cavity accompany the ar *spheno-palatine vein* emptying itself into the pterygoid plexus; the *veins* joining the ophthalmic, and small veins passing out at the mar nares to join the coronary vein of the upper lip. Some small veins the nasal bone and the ascending process of the superior maxilla to join mencement of the facial vein.

The *lymphatics* are abundant and large. They form a close plex mucous membrane, the branches extending almost to the surface, and a plexus of valved vessels nearer the bone. These are in communicatio lymphatic spaces which enclose the branches of the olfactory nerve, spaces again communicate with the subdural space of the cranium, s lymphatics of the nasal mucous membrane can be injected from t cavity (Schwalbe).

THE THORACIC VISCERA.

greater part of the thorax is occupied by the lungs, each of which ted by a serous membrane, the *pleura*. The heart, enclosed by a anous covering, the *pericardium*, lies between the lungs in the of a space bounded laterally by the right and left pluræ, and as the *mediastinal space* or simply as the *mediastinum*. The term *mediastinum* is used to denote the part of this space immediately of the pericardium ; *middle mediastinum* that which contains and by the pericardium ; and *posterior mediastinum* the part behind the dium ; whilst the upper part of the space, which is situated above icardium and extends as far as the root of the neck, may con- tly be distinguished as the *superior mediastinum*.

superior mediastinum may be considered as bounded below by a passing through the lower part of the body of the fourth dorsal a behind, and the junction of the manubrium with the body of rnum in front. Its upper limit corresponds with the superior re of the thorax. In front are the manubrium and the lower ends sterno-hyoid and sterno-thyroid muscles ; and behind are the our dorsal vertebræ and the lower ends of the longus colli muscles. ontains the trachea, œsophagus and thoracic duct ; the whole of ansverse part of the arch of the aorta, the innominate artery, and parts of the left common carotid and subclavian arteries which are ned within the thorax ; the innominate veins and upper part of perior vena cava ; the phrenic and pneumo-gastric nerves, the left rent, and the cardiac nerves ; and the cardiac lymphatic glands and ns of the thymus gland.

separate description of a superior mediastinum was suggested by Struthers al of Anatomy, Vol. III.) and is manifestly convenient. The superior medi- m as here defined is not identical however with that of Struthers, who the plane marking off the lower boundary pass a vertebra higher behind gh it is at the same level in front) and this puts the whole of the arch of rta into the middle mediastinum. The plane proposed by Struthers does owever, in the majority of cases pass above the arch, but cuts off the upper f its transverse portion, and it has also the disadvantage of being so e that the superior mediastinum cannot properly be said to be the part be- the manubrium. On the other hand the plane here proposed is nearly ntal, and in the average condition passes just under the transverse portion arch, and this coincides with the extent upwards of the pericardium ; and t above the roots of the lungs.*

e **anterior mediastinum** is narrow in its upper half, the two e coming nearly or quite into contact behind the second piece of the um. Below it is broader, the left pleura receding from its fellow, s bounded in front by the sternum with the fifth and sixth, and a portion of the seventh left costal cartilages, and by the triangularis i muscle ; behind it is the pericardium. This space contains only areolar tissue, and in its lower part two or three small lymphatic s (anterior mediastinal glands).

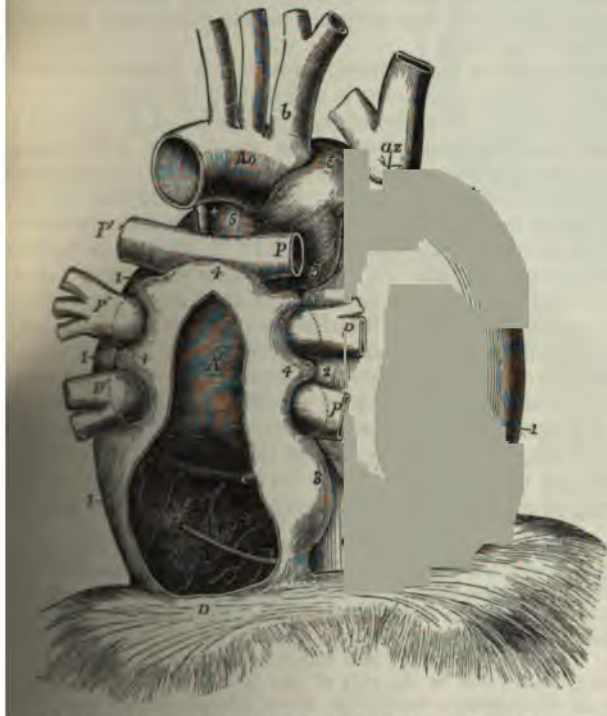
e **middle mediastinum** is the enlarged central portion of the e space, containing in addition to the pericardium with its contents

he above account of the superior mediastinum has been furnished by Professor . (R.A.S.)

er part surrounds the trunks of the great vessels. It consists of ers, one external and fibrous, the other internal and serous.

fibrous layer is a dense, unyielding membrane, consisting of which interlace in every direction. This layer is attached below to per surface of the diaphragm (fig. 419, D), partly to the central , partly to the adjoining muscular surface, especially on the left

Fig. 419.



.—SEMI-DIAGRAMMATIC VIEW OF THE PERICARDIUM FROM BEHIND, DESIGNED TO THE PRINCIPAL INFLECTIONS OF THE SEROUS SAC ROUND THE GREAT VESSELS Thomson). ½

rawing is taken from preparations in which the heart and vessels had been filled by injection, the pericardium inflated and dried in the distended state, and s continuation on the vessels removed. By the removal of a portion of the ium from behind the right and left cavities of the heart, the position of that made apparent. *A*, right auricle ; *A'*, left auricle ; *V*, right ventricle ; *V'*, left ; *Ao*, aortic arch ; *b*, innominate artery ; *C*, vena cava superior ; *az*, azygos , vena cava inferior ; *c''*, great coronary vein ; +, cord of the ductus arteriosus ; *P'*, left pulmonary artery ; *p*, right, *p'*, left pulmonary veins ; *D*, central tendon diaphragm ; 1, sac of the pericardium ; 2, the portion on the right side which surrounds the vena cava superior, the right pulmonary veins, and the vena cava ; 3, portion on the left side which partially surrounds the vena cava inferior ; 4, which is extended upwards behind the left auricle, and partially folds over the ry arteries and veins, meeting between these different vessels the extensions of from the right and left ; 5, tubular portion which completely surrounds the aortic monary arterial trunks. A bent probe is passed within the pericardium from the right auricle, in front of the vena cava inferior, to the back of the left ventricle, ay indicate the place where the large undivided sac of the pericardium is folded hat vein.

side. Near the median line the connection is very firm, th structures being continuous; elsewhere the attachment is more is effected mainly by areolar tissue. The pericardium is fixe front by two ligamentous bands which pass to it from the m and ensiform process of the sternum (Luschka). The fibrou continued above for some distance along the large blood-vess form of tubular prolongations, which become gradually lost u external coats. The superior vena cava, the four pulmonary aorta, and the right and left divisions of the pulmonary arter investments of this kind.

The **serous** layer of the pericardium not only lines the fib but, like other serous membranes, is reflected on the surface of which it invests. It has, therefore, a visceral and a parieta The parietal portion adheres firmly to the fibrous membra reflected and becomes continuous with the visceral portion a shor along the great vessels, about 1 to $1\frac{1}{2}$ inches from the base of In passing along the aorta and pulmonary artery, it encloses th in a common short tubular sheath (fig. 419, 5, 5). It is refl upon the superior vena cava (c), and on the four pulmonary vei and forms a deep recess behind, between the entrance of the righ veins into the left auricle. The inferior vena cava (c′) receives o scanty covering of this membrane (3, 2), inasmuch as that ves the right auricle almost immediately after passing through the di and is only partially surrounded by a reflection of the perica the narrow interval between these parts. None of the vessel joining the heart, with the exception of the aorta and pulmona where they are united together, receive a complete covering f pericardium, or can be said to be entirely enveloped in the sac.

When the left pulmonary artery and subjacent pulmonary vein are a fold of the pericardium will be seen between them, which has been t Marshall the "vestigial fold." It is formed by a duplicature of t layer, including areolar and fatty tissue, together with blood-vessels an and is from half to three-quarters of an inch in length, and from h inch deep. It extends from the left superior intercostal vein above monary artery downwards to the side of the left auricle, where it is narrow streak which crosses round the lower left pulmonary vein. encloses a vestige of a *left* superior vena cava (duct of Cuvier), which early embryonic life. (Marshall, "On the development of the gre veins in Man and Mammalia," Philosoph. Trans., 1850.)

The pericardium is in relation in front and behind with the medi their contents. Anteriorly also it is covered by the pleuræ and to so by the lungs, except below, where it approaches the surface in the ang to the left of the lower part of the sternum. At the sides it is in co the phrenic nerves, as well as with the pleuræ and their contained vi relations to the diaphragm and great vessels have been already noticed

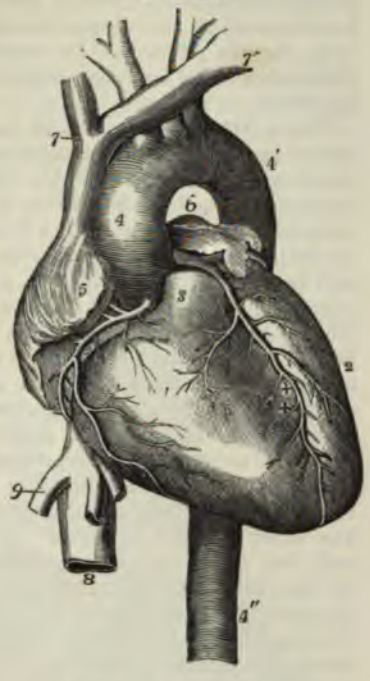
In structure the serous layer of the pericardium agrees with that membranes generally, being formed of connective tissue containing a elastic fibres, blood-vessels and lymphatic vessels.

THE HEART.

The heart is a hollow muscular organ, divided by a longitu tum into a right and a left half, each of which is again subdiv transverse constriction into two compartments, communica each other, and named **auricle** and **ventricle**. Its genera

= of a blunt cone. Enclosed, as before said, in the pericardium, it

Fig. 420.

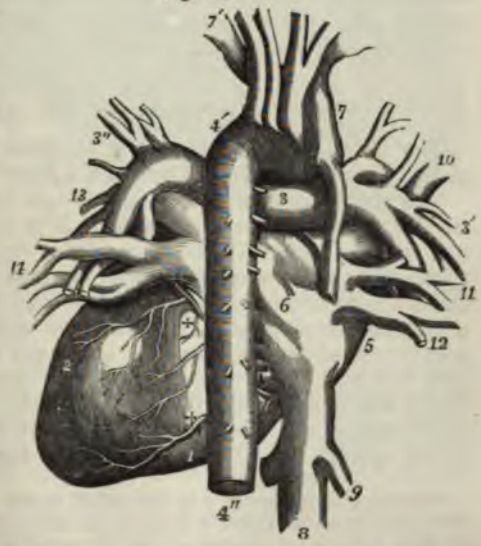


420.—THE HEART AND GREAT VESSELS OM BEFORE (R. Quain). ½

e pulmonary artery has been cut short to its origin in order to show the first of the aorta. 1, right ventricle; 2, ventricle; 3, root of the pulmonary y; 4, 4', arch of the aorta; 4'', the ending aorta; 5, the appendix and rior part of the right auricle; 6, e of the left auricle; 7, 7', innoate veins joining to form the vena superior; 8, inferior vena cava w the diaphragm; 9, one of the large tic veins; +, right; + +, left coroartery.

laced behind the sternum and costal cartilages (fig. 430; on e 492), the broader end, or e being directed upwards, kwards, and to the right, and ending from the level of the h to that of the eighth dorsal tebra; the apex downwards, wards, and to the left. In the ng subject its stroke against wall of the chest is felt in the ce between the cartilages of fifth and sixth ribs, a little ow and to the inner side of

Fig. 421.



421.—VIEW OF THE HEART ND GREAT VESSELS FROM EHIND (R. Quain). ½

, right ventricle; 2, left tricle; 3, right pulmonary ry; 3', its branches passing o the root of the right lung; the same of the left; 4', h of the aorta; 4'', descend- aorta; 5, right auricle; 6, placed on the division be- en the right and left auricles; superior vena cava; 7', left minate vein; 8, inferior cava; 9, right hepatic ; 10, 11, 12, right pul- ary veins; 13, 14, left pul- ary veins; +, +, branches he right and left coronary ries.

left nipple ($3\frac{1}{4}$ es from the middle of sternum and $1\frac{1}{2}$ below the nipple): he dead body the apex little higher than during life. The heart, therefore, has a very

oblique position in the chest, and projects farther into the l into the right half of the cavity. Its position is affected to a extent by that of the body; thus it comes more into contact v anterior wall of the chest when the body is in the prone posti lying on the left side. In inspiration, on the other hand, w diaphragm sinks and the lungs expand, it recedes slightly fr chest-wall.

The heart is attached at its base to the great blood-vessels, serous layer of the pericardium is here continued on to it. Ot the heart is entirely free within the sac of the pericardium. The anterior surface looks somewhat upwards as well as forwards tow sternum and costal cartilages: from these it is for the most part se by the pleuræ. The lungs also advance over it to some extent, and e still farther during inspiration, so as in that condition to leave triangular part, not more than two square inches in extent, unco The posterior or under surface is flattened, and rests on the diap Of the two borders or margins formed by the meeting of the a and posterior surfaces, the right or lower border, called *margo ac* comparatively thin, and is longer than the upper or left border, v more rounded and is named *margo obtusus*.

A deep transverse groove, the *auriculo-ventricular furrow*, divi heart into the auricular and the ventricular portions; and on t tricular portion two *longitudinal furrows*, situated one on the a the other on the posterior surface, mark its division into r and left chamber. They extend from the base of the ven portion, and are continuous one with the other a little to the l the apex, which is thus formed entirely by the wall of the left ve The anterior longitudinal furrow (fig. 420, + +) is nearer to the l the posterior furrow nearer to the right side of the heart, the rig tricle forming more of the anterior, and the left more of the po surface of the organ. In the furrows run the coronary arteries an with lymphatic vessels and nerves, embedded in fatty tissue and c by the visceral layer of the pericardium.

CAVITIES OF THE HEART.

The heart, as before remarked, contains four chambers or co ments, a right and a left auricle and a right and a left ventricle.

The **right auricle** (fig. 420, 5) is best brought into view on t the heart somewhat to the left side; it is then seen to occupy th and anterior portion of the base of the organ. When thus vie auricle appears of a quadrangular form, the superior and inferio cavæ, occupying respectively the upper and lower posterior angles, a tongue-shaped portion, the *auricular appendix* or *auricle* pro seen to project from the anterior and upper angle and to turn to t over the root of the aorta. The main part of the auricle, tha which the great veins directly pour their blood, is commonly *sinus venosus* or *atrium*, to distinguish it from the auricular ap When opened, the interior of the right auricle presents a smoo

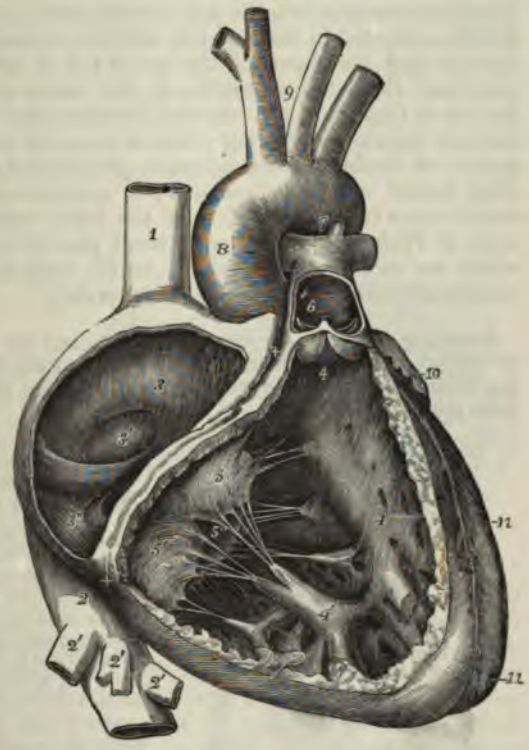
* This uncovered part may be marked off on the surface of the chest by t drawn from the point of the apex-beat to the middle line of the sternum, one ha the other extending obliquely upwards to between the fourth cartilages.

† So termed from its resemblance to the external ear of some animals.

ace, except in the appendix which is ridged vertically with
t reticulated muscular bands, and upon the anterior wall of
where similar bundles are seen extending, but here running
th one another, like the teeth of a comb, and thence termed
ctinati.

sterior wall corresponds with the partition between the two
eptum auricularum). Near its lower part and just above and
of the orifice of the inferior vena cava is an oval depression,
or *fossa ovalis* (fig. 422, 3′), the remains of the *foramen ovale*

Fig. 422.



-INTERIOR OF
F AURICLE AND
, EXPOSED BY
OF A PART OF
GHT AND AN-
VALLS (Allen
½

r vena cava;
ena cava; 2′,
s; 3, septum
les; 3′, fossa
istachian valve
; 3″, aperture
coronary vein
'e; +, +, au-
icular groove,
ortion of the
alls of the
ventricle hav-
served; 4, 4,
m, the cavity
ventricle; 4′,
ior papillary
eft; 5′, right,
erior or septal
the tricuspid
monary artery,
anterior wall
l having been
nd a narrow
t preserved at
cement where
ary valve is
, concavity of
ch close to the
ductus arterio-
cending part
covered at its commencement by the auricular appendix and pulmonary
laced between the innominate and left common carotid arteries; 10, appendix
uricle: 11, 11, left ventricle.

foraminis ovalis), which is an open passage in the fœtal heart
right to the left auricle. The *fossa ovalis* is bounded above
ie sides by a prominent border, deficient below, the *annulus*
sthmus Vieussenii, whilst the floor of the fossa, formed by what
iously a valve, is thin and translucent; and occasionally
blique passage leading into the left auricle is left between it
annular border. At the right part of the cavity are seen the
the superior and inferior venæ cavæ, the former passing down-
d forwards, the latter, the larger, being directed upwards and

inwards. Between the two orifices is a slight projection, bet in certain quadrupeds than in man, which has received the misleading name of *tubercle of Lower*.

In front of the orifice of the inferior vena cava, and partly co a crescentic fold of the lining membrane, the *Eustachian val* continuous by its convexity with the margin of the venous o its anterior cornu is prolonged into the anterior limb of ovalis. This valve, which is very variable in character in the often cribriform or perforated with holes, is an important the fœtal heart, and serves the purpose of directing the stre from the inferior vena cava through the foramen ovale into th The other openings into the right auricle are 1,—the *auricul aperture*, situated in front of the inferior vena cava and oc anterior and under part of the cavity: it is oval in form admitting three fingers easily; 2, the *orifice of the coron* the heart (fig. 422, 3″), situated between the inferior ca auriculo-ventricular opening: this is guarded by a semicir sometimes double, which, although previously figured by E often named valve of Thebesius; 3, *openings of* two or th *cardiac veins* from the surface of the right ventricle; and *mina of Thebesius*, a number of small pits variously situat which are merely recesses closed at the bottom, whilst oth mouths of small veins (*venæ minimæ cordis*).

According to L. Langer the foramina Thebesii are not confine auricle but occur in all the cavities of the heart; and into some of the ventricles, small veins which proceed from the muscular sub heart open.

Fig. 423.

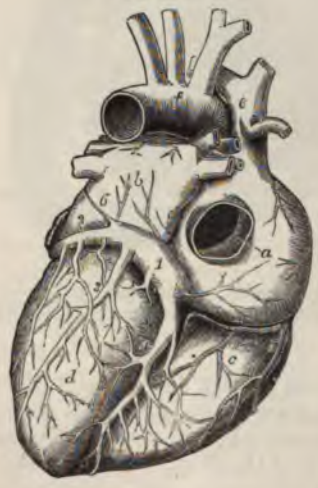


Fig. 423.—View of the adul behind, to show the corona Thomson). ½

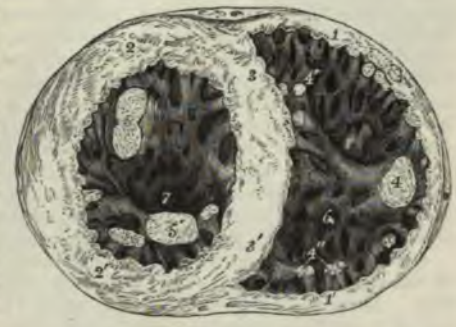
a, placed on the back of th points to the Eustachian val the opening of the inferior ve auricle; *c*, right ventricle; *d*, *e*, vena cava superior; *f*, arch 1, coronary sinus; 2, great coro ing round the heart in the auri groove; 3, posterior cardiac v cardiac vein; 5, one of the anter passing directly into the right vestige of the left superior ven ing over the left auricle downw coronary sinus.

The coronary vein (fig. 4 siderably dilated before i auricle, and this dilated po embedded in the posterior w auricle, is termed the "co At the junction of the coro the dilated portion there is sisting of one or two seg small veins likewise enter the coronary sinus, each of them p valve. One of these small veins, the "oblique vein" of Mars 6), takes a straight course from the vestigial fold before mentio back of the left auricle, to open into the coronary sinus. This vein

orifice: it, together with the coronary sinus, is to be looked upon as mnant of the original left superior vena cava of the embryo (vide antea,

right or **anterior ventricle** (fig. 420, 1) occupies the chief part anterior surface of the heart, the right border, and a smaller on of the posterior surface. It extends nearly, but not quite, he apex. The upper and left angle is prolonged in a conical to the commencement of the pulmonary artery: this part of entricle is named *conus arteriosus*, or *infundibulum*. The muscular of this ventricle is thickest at the base, and becomes thinner rds the apex. When the cavity is laid open (fig. 422) the septum e heart is seen to bulge into it, so that in cross section this ventricle escentic in form (fig. 424, 6). At the base of the ventricle are two ces, protected by valves; the *auriculo-ventricular*, of an oval , and situated towards the right, and that of the *pulmonary y*, smaller, more elevated, and towards the left. Between the two wall of the cavity projects downwards, in the form of a thick

Fig. 424.



424.—Cross Section of the entricular part of the eart at two-thirds from the pex looking downwards into e Cavities (Allen Thomson). ⅔

1', Wall of the right ventricle; wall of the left; 3, 3', septum; e principal papillary muscle of ight ventricle; 4', some columnæ on the septum near the front; others posteriorly near the sep- ; 5, 5', the principal papillary eles of the left ventricle; 6, deepest part of the cavity of the t ventricle; 7, that of the left tricle at the apex of the heart.

nded muscular partition. The inner surface is marked by muscular ndles, "columnæ carneæ," some of which are attached by each remity to the wall of the ventricle and are free in the middle, others only sculptured in relief, as it were, being continuous with the ll of the ventricle in their whole length; while a third set, forming principal bundles, an anterior and a posterior, named *musculi illares*, are connected at their base with the ventricular wall, and by other end are attached to small tendinous cords (*chordæ tendineæ*), ough which they are connected with the segments of the auriculo- tricular valve. The inside of the conus arteriosus is smooth, and free n columnæ carneæ.

he valve guarding the right auriculo-ventricular opening is com- d of three triangular segments, or flaps (right, left or infundibular, posterior or septal), and is hence named the *tricuspid*. The flaps mainly formed of fibrous tissue covered by endocardium. At r bases, they are continuous with one another, so as to form an ular membrane attached around the margin of the auricular open- : they are directed downwards, and are retained in position within ventricle by the chordæ tendineæ, which are attached to their ricular surfaces *and free margins*. The middle part of each seg-

ment is thicker than the rest, whilst the marginal part is parent, and jagged at the edges (compare fig. 428, B, *c*, *c'*).

The chordæ tendineæ from the anterior papillary muscle pa between the right and left segments, to be attached to both: the ch from the posterior papillary muscle are attached in like manner to posterior segments; while others forming a third set spring directl face of the septum, sometimes from small eminences upon it, and to be attached to the adjacent borders of the left and posterior seg

During the contraction of the ventricle, the segments of the val to the opening leading from the auricle, and prevent the blood back into that cavity. Being retained by the chordæ tendineæ, flaps of the valve resist the pressure of the blood, which would o them back through the auricular orifice; the papillary muscles, the cavity of the ventricle itself shortens, prevent the valve fro much towards the auricle. In the angles between each pair of segments of the auriculo-ventricular valves there may be found, stantly, as many small intermediate lobes.

According to Kürschner (Wagner's Handwörterbuch, art. "He there are three kinds of cords to each segment; *a*, the first set ge four in number and proceeding from two different sets of papillæ, these and the wall of the ventricle, run to the attached margin o and are there connected also with the tendinous ring round the aur lar opening; *b*, the second set, more numerous, and smaller than th also from two adjacent papillary muscular groups, and are attach to the back or ventricular surface of each segment along two or tending from the points of attachment of the tendons of the fir base of the valve to near its free extremity; *c*, the third set, which numerous and much finer, branch off from the preceding ones, an to the back and edges of the thinner marginal portions of the v muscular fibres prolonged from the neighbouring walls of the aur into the segments of the auriculo-ventricular valves; blood-vess these but in all other parts the valves are non-vascular (L. Langer).

A fibrous band, sometimes muscular, is often found stretching ac of the right ventricle from the base of the anterior papillary musc tum. It represents the strong "moderator" band found in the h and of some other mammals, and in that of birds (Rolleston).

The valve at the orifice of the pulmonary artery cons flaps, a right and left and a posterior, named from their sha or *sigmoid* (fig. 422; fig. 427, I): they are constructed simil on the left side at the root of the aorta: and as the characte named are better marked, the more complete description wil until these are treated of.

The **left auricle** occupies the left and posterior part of the heart. The atrium presents from behind, where it a quadrilateral appearance (fig. 423, *b*). In front it is in the aorta and pulmonary artery; behind, it receives two pul on each side, those from the left lung entering very close t the right, it is in contact with the other auricle. The *auri age* (fig. 420, 6) is the only part of the left auricle seen fro it extends forwards from the left side of the atrium, and cu the right side, resting on the pulmonary artery. It is mo well as longer and narrower than that of the right aur margins are more deeply indented.

The interior of the appendix presents musculi pectina similar to those in the right side of the heart, but the walls

e altogether smooth and even, and are also thicker than those ht auricle. Posteriorly the openings of the pulmonary veins sually two on each side, and without valves (fig. 425, 1). The of one or both sides sometimes unite into one before entering , whilst in other cases there is found an additional opening,

Fig. 425.

HE LEFT AURICLE RICLE OPENED AND OF THE WALL RE- AS TO SHOW THEIR (Allen Thom-

nencement of the rtery has been cut to show the aorta : into the left ven- en carried a short the aorta between semilunar flaps ; auricle with its as been removed. right pulmonary hort ; 1′, placed cavity of the he left side of the on the part which mains of the valve ramen ovale, of rescentic border is a narrow portion of the auricle and eserved around the tricular orifice ; 3, ace of the wall of le, seen to become thinner towards 3″, ; 4, a small part of the left ventricle een preserved with papillary muscle it ; 5, 5, right uscles ; 5′, the left septum ventriculo- e anterior or aortic d 6′, the posterior segment of the e ; 7, placed in the interior of the aorta near its commencement and alve ; 7′, the exterior of the great aortic sinus ; 8, the upper part of the iosus with the root of the pulmonary artery and its semilunar valves ; 8′, ed portion of the pulmonary artery remaining attached to the aorta by 9, f the ductus arteriosus ; 10, the arteries rising from the summit of the

uently on the right side. In the lower and fore part of the situated the left *auriculo-ventricular* orifice. It is of an oval is rather smaller than the corresponding opening between the icle and ventricle. On the septum between the auricles, a lepression may be observed (1′), comparable to a mark made ger-nail on a soft surface. This is the vestige of the foramen it appears on the left side. The depression is limited by a scentic ridge, *the concavity of which* is turned upwards, and

which is in fact the border of the now adherent membran
which during fœtal life is applied to the left side of the then
men ovale. The line of adhesion may vary so as to leave men
a pocket-like recess.

The **left** or **posterior ventricle** occupies the left border of
but only about a third of its extent appears on the anterior s
rest being seen behind. It is longer and narrower than
ventricle, and the cross section of its cavity is oval, not cre
septum on this side being concave (fig. 424). Its walls, whic
near the apex, are nearly three times as thick as those o
ventricle, are thickest at the part where the ventricle is w
one-fourth of its length from the base (fig. 425, 3); from
they become thinner towards the auricular opening, and still
wards the apex (3″), which is, therefore, the weakest part.
membrane, which is continuous with that of the left auri
aorta, is usually less transparent than that of the righ
especially in later life. In the interior of the cavity are notic
carneæ, musculi papillares with chordæ tendineæ, and
guarded with valves. The *columnæ carneæ* are smaller than

Fig. 426.

Fig. 426.—View of the base of the ventricular part of the hea
the relative position of the arterial and auriculo-ventricul
(Allen Thomson). ⅔

The muscular fibres of the ventricles are exposed by the removal of the
fat, bloodvessels, &c.; the pulmonary artery and aorta and the auricles h
moved. The valves are in the closed condition. 1, 1, right ventricle; 1
riosus; 2, 2, left ventricle; 3, 3, the divided wall of the right auricle; 4
left; 5, the left, 5′, the right, and 5″, the septal segment of the tricuspid
anterior or aortic, and 6′, the posterior or parietal segment of the mitral
angles between these segments are seen smaller fringes); 7, the pulmona
placed upon the root of the aorta; 9, the right, 9′, the left coronary artery.

right ventricle, but are more numerous and more closely
Their intersections are very numerous near the apex of the
also along its posterior wall, but the upper part of the anterio
septum is comparatively smooth. The *musculi papillares* (4,

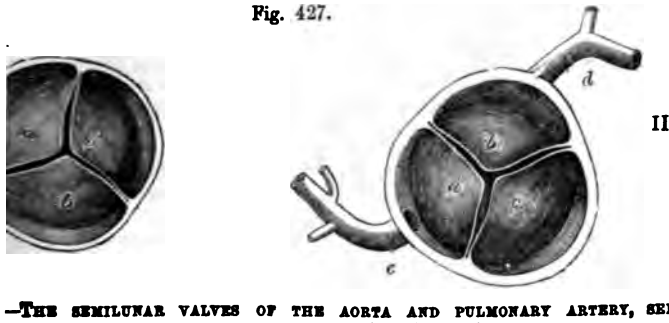
two groups, which are larger than those of the right ven-
he two orifices of this ventricle are situated very close together,
of the segments (fig. 426, 6) of the auriculo-ventricular valve
the auricular opening is placed at the left and posterior part
e of the ventricle; the aortic opening, in close proximity in
towards the right.

spid or *mitral* valve (fig. 426, 6 6'), at the left auricular opening,
in structure the tricuspid valve of the right ventricle, but it is
ker and stronger in all its parts, and consists of only two
egments, continuous at their attached bases. The larger of
egments is suspended obliquely to the right and in front of the
tween the auricular and aortic openings: the smaller to the left
nd, and close to the wall of the ventricle. There is usually
r lobe at each angle of junction of the two principal seg-
ore apparent than those between the segments of the tricuspid

he right side, the two sets of chordæ tendineæ from the papillary
oceed each to an angle between the two segments, and are attached in
er to their margins and ventricular surfaces (fig. 426, and fig. 428 B, *e*),
e musculi papillares, when they contract, tend to bring the edges of the
her. The chordæ tendineæ are stronger and less numerous than in the
ricle. Small bands, partly muscular partly tendinous, may often be
sing the cavity of the ventricle in various directions. They appear to
s of the spongy structure of the cavity during a part of embryonic life.

terial or *aortic orifice* circular in form, and smaller than the
, is separated from it only by the attachment of the anterior
of the mitral valve. As in the pulmonary artery, its valve
of three semicircular flaps (*semilunar* or *sigmoid*,) (fig. 427, II)
which is attached by its convex border to the side of the artery

Fig. 427.



—THE SEMILUNAR VALVES OF THE AORTA AND PULMONARY ARTERY, SEEN FROM THEIR DISTAL SIDE (Allen Thomson).

erse section of the pulmonary artery immediately above the attachment of the valves: *a*, the left, and *c*, the right anterior segments; *b*, the posterior segment: ch the sinus of Valsalva is seen, and the attachment of the valve-segments to wall of the artery.

ilar section of the aorta: *a*, the left posterior segment, *b*, the anterior segment, orresponding sinuses of Valsalva, from which the coronary arteries are seen to origin; *c*, the right posterior segment; *d*, the right, and *e*, the left coronary

uld appear that the above nomenclature most correctly describes the relative the valve-segments. Those of the pulmonary valve are often, however, spoken sterior, *a*, and two posterior; and those of the aortic, as a posterior, *c*, and er.

at the place where it joins the ventricle, whilst its other bo
straight, is free, and projects into the interior of the vessel.

Fig. 428.

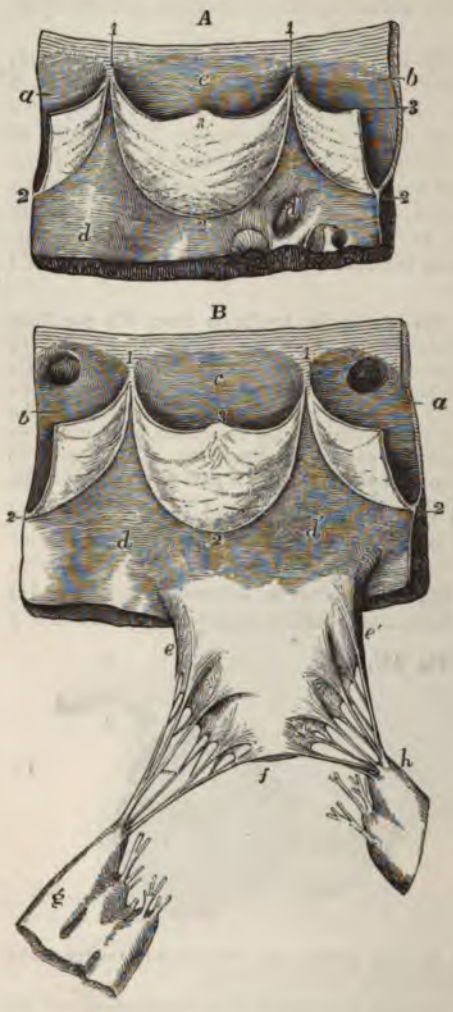


Fig. 428.—Views
THE SEMILUNAR
VALVES, AS SEE
THE VENTRICLE
son).

A, portion of
artery and wall o
tricle with one en
two half segment
a, *b*, *c*, sinuses o
site the segment
surface of the
curved attached b
ments ; 3, the mi
border (corpus Ar

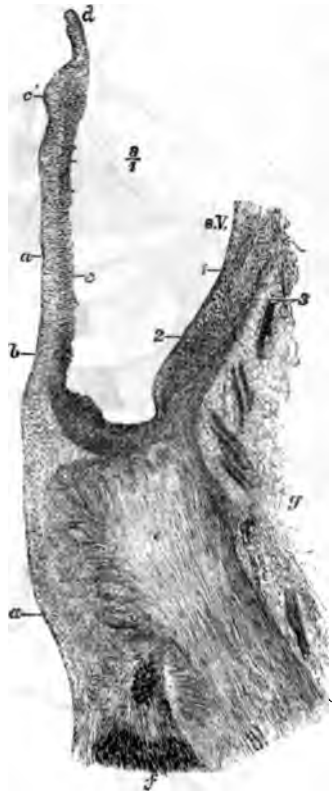
B, portion of th
of the left ventricl
segment and two
the aortic valve,
anterior segment
valve ; *a*, *b*, *c*, sin
opposite the segm
b, the apertures
arteries are seen ;
surface of the wall
1, 2, and 3, as b
base of the ante
the mitral valve ;
tween *e*, and *e'*, an
ment of the br
tendineæ to the m
surface of the val
right, *h*, left prin
muscle : the cut el
are those which be
terior segment an
intermediate segm

The segments
are composed of
covered by a pr
the endo-cardiu
side, and of the
the artery on th
Their thickness
rent parts. A te
strengthens the
the valve, and
of that margin there is a slight fibro-cartilaginous thickening, t
corpus Arantii (fig. 428, 3). Other tendinous fibres, arising from
border, run in the valve towards the nodule ; occupying its whole
two narrow lunated portions, one on each side, adjoining the free
valve. These parts, which are named *lunulæ*, are therefore
the rest. There is also a strengthening fibrous cord surrounding
border of each valve. The wall both of the aorta and pulmonary a
out opposite each semilunar flap : these bulgings are known as
Valsalva. In the aorta these are situated one anteriorly and two pos
and left). From the anterior arises the right coronary artery;

left coronary artery: these vessels being for the supply of blood to e of the heart.

Fig. 429.

SCTION THROUGH ONE OF OF THE AORTIC VALVE, AND E CORRESPONDING SINUS OF WITH THE ADJOINING PART VENTRICULAR WALL. (V.).



lium, prolonged over the ndocardial tissue; *c*, fibrous valve, thickened at *c'* edge; *d*, section of the ction of the fibrous ring; res of the ventricle attached areolar tissue at the base le; *s. V.*, sinus Valsalvæ; middle, and outer coats of

ity of the sinuses of greater, and the tendi- in the valves is more ked at the mouth of the t the commencement of y artery.

f the left ventricle ad- oot of the aorta forms partment, the "*aortic* Sibson, the walls of rous, or, in some parts, inous, so that it remains and allows space for laps of the aortic valve uring diastole.

OF THE PARTS OF THE HEART WITH RELATION TO THE WALL OF THE THORAX.

o-thirds of the bulk of the heart lie to the left of the middle 0). The *right auricle* (3') lies behind the sternal ends of the and fifth costal cartilages, and the intervening portions of tal spaces, and is also partly covered by the right edge of the he point of its auricular appendage is exactly behind the on a level with the upper border of the third costal carti- The *left auricle* extends vertically from the level of the lower he second left cartilage to the upper border of the fourth); and in breadth corresponds to the body of the eighth bra and the head of the adjoining rib. The apex of its 4) is in the lower part of the second intercostal space or third costal cartilage, about an inch and a quarter from the sternum. The *right ventricle* extends from above down from the sixth cartilages on the left side. The conus arteriosus projecting part, being uncovered by lung. The auriculo-

Fig. 430.

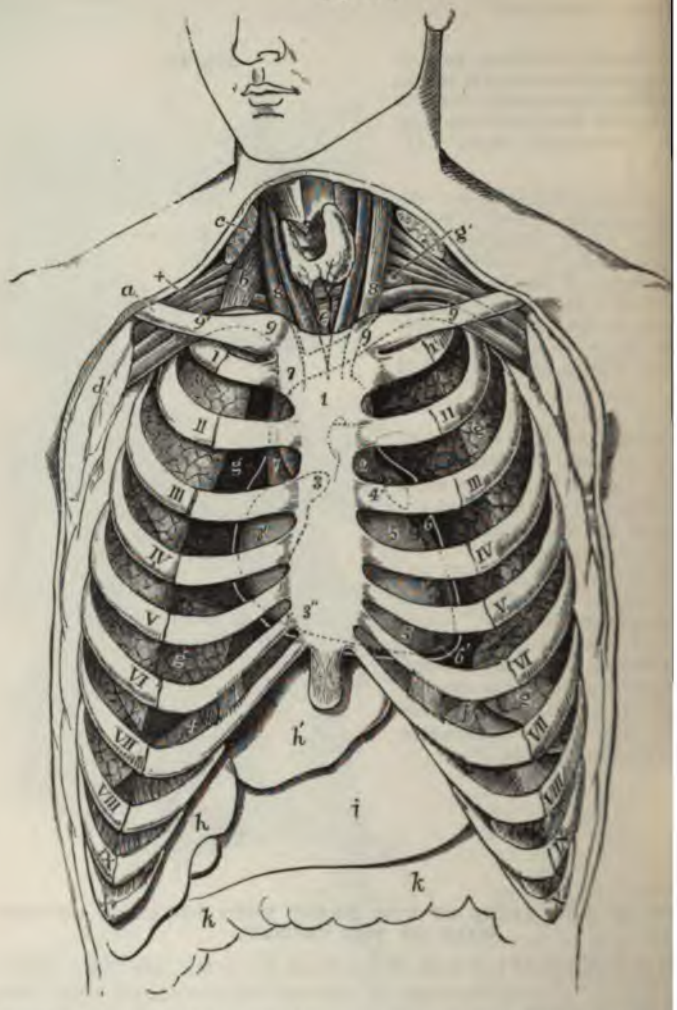


Fig. 430.—SEMI-DIAGRAMMATIC REPRESENTATION OF THE CHEST, TO SHOW THE ... OF THE HEART AND GREAT VESSELS, AS SEEN BEHIND THE STERNUM AN... CARTILAGES (A. Thomson, modified from Luschka). ½

The lungs have shrunk from the front of the chest. The heart is slightly ... than during life, and the aorta more to the right. *a*, right clavicle; *b*, ... anticus muscle; *c*, sterno-mastoid muscle divided; *d*, pectoral muscles ... +, axillary nerves above the subclavian artery; *e*, trachea below the isthmus ... thyroid body; *f*, *f*, upper surface of the diaphragm; *g*, *g*, lungs; *g'*, on the l... apex of the lung appearing in the neck; *h*, right, *h'*, left lobe of the liver; *i*, st... *k*, *k*, transverse colon; I, to X, first to tenth ribs near their cartilages; 1, pl... the lower part of the manubrium of the sternum, and over the arch of th... (indicated by dotted lines); 2', placed in the second left intercostal space, on the ... the pulmonary artery; 3, appendix of the right auricle; 3', on the sinus venosus, ... the third space; 3'', its lower part at the junction of the sixth and seventh ri... tilages with the sternum; 4, left auricular appendix; 5, 5, right ventricle; 6, left v...

...t of the heart: the white line outside the heart is intended to indicate the external ...illum, as if the anterior half were removed by a transverse incision; 7, 7, vena ...perior; 8, 8, internal jugular veins; 9, 9, subclavian veins, joining the jugular; ...7, innominate veins; the right rising behind the sterno-clavicular articulation, the ...ning obliquely behind the upper half of the manubrium. The position of the first ...of the innominate artery, left carotid and left subclavian arteries, is indicated be...and below this vein; 9', 9', outer part of the subclavian arteries. It is to be observed ...n this figure the attachment of the sixth costal cartilage to the sternum is represented ...s too high.

...*icular sulcus* corresponds with a line drawn obliquely upwards from ...the sternal end of the sixth costal cartilage on the right side, to ...third cartilage on the left. The *rounded margin* formed by the left ...ricle extends on the left side from the third cartilage to a point in ...fifth space two inches vertically below the nipple. The *sharp margin* ...ed by the right ventricle passes from the sternal end of the sixth ...age on the right, and passes transversely behind the seventh right ...age, the ensiform (at its upper third), and the seventh left cartilage, ...eet the other margin at the apex.

...he *apex of the heart* (fig. 430, 6') is situated about 3½ inches to the ...of the middle line, in the fifth intercostal space, close to the upper ...gin of the sixth rib.

...he *auriculo-ventricular openings* lie slightly to the left of the line of ...auriculo-ventricular sulcus. The *right orifice* lies behind the sternum, ...level with the fourth intercostal space. The *left* is behind the left ...of the sternum, on a level with the fourth costal cartilage. The ...e *of the pulmonary artery* is placed immediately to the left of the ...num, behind the edge of that bone and the third cartilage, and ...pulmonary trunk extends up to the second left cartilage. The ...c *orifice*, also partly behind the left half of the sternum, is on a ...tly lower level than the orifice of the pulmonary artery (being ...site the lower part of the third cartilage and the third intercostal ...e), and is covered by it in one-fourth its diameter. The aortic ...e is exactly behind the posterior wall of the conus arteriosus.

INTIMATE STRUCTURE OF THE HEART.

...he heart is closely invested by a serous membrane, the cardiac peri...ium (*epicardium*), and its cavities are lined by a smooth membrane, ...ed the *endocardium*, but the main substance of the organ is com...d of muscular tissue (*myo-cardium*), with a certain amount of ...stitial areolar tissue and numerous blood-vessels, lymphatics, and, ...me parts, nerves and ganglia. There is also a considerable amount ...t chiefly collected at the base of the heart and beneath the peri...ium, while in connection with the large orifices at the base of the ...ricles a mass of fibrous tissue and fibro-cartilage occurs, which in ...animals, as the ox, is bony, and is known as the *os cordis*. This ...al fibro-cartilage is placed in the angle between the aortic and the ...auriculo-ventricular openings (see fig. 426), and from it pro...s pass in various directions. One of these extending downwards ...eet the fleshy septum of the ventricles, separates the left ventricle ...the right auricle, forming the right boundary of the aortic vestibule. ...e processes form the bases of what have been described by authors ...e *fibrous* or *tendinous rings* of the auriculo-ventricular and arterial ...ngs. The fibrous tissue of these rings is continuous with that ...t is found in the segments of the valves, strengthened on the sides

next the septum by the processes from the fibro-cartilage. ' the arterial orifices give attachment below to some of t fasciculi of the ventricle, whilst above they project betwee the valves, with the curved border of which they are contin as with the middle coat of the artery. The fibres of the m the artery, here comparatively thin, are not arranged ann other parts of the vessel, but converge to the intervals sinuses of Valsalva, to be attached to the projections of the

Fig. 431.

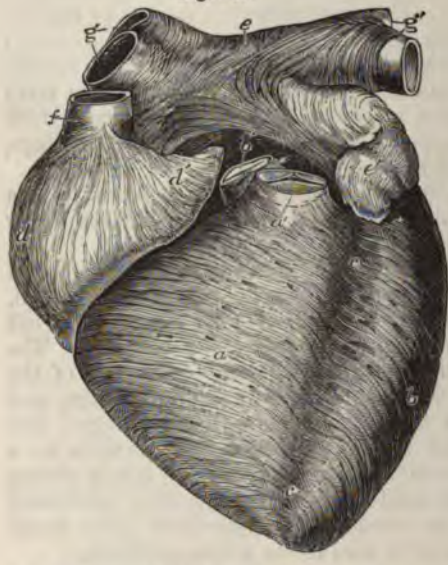


Fig. 431.—Ant HEART OF A DISSECTED AF ING, TO SHOW MUSCULAR FIB SON). ⅔

This figure is of Luschka's, bu chiefly taken f preparation. T pulmonary arter cut short close valves, so as to s fibres of the au ficial layer of t right ventricle; left; *c*, *c*, anter lar groove, from ary vessels hav *d*, right auricle; both showing chi fibres; *e*, upper auricle; betwee transverse fibres aorta pass acro *e'*, appendix of le perior vena cav near the auricle are seen; *g*, *g'*, right and left pulmonary veins with circular surrounding them.

The tendinous rings of the aortic and left auricular orifices so that when the fibrous tissue is destroyed by boiling the run into one.

ARRANGEMENT OF THE MUSCULAR FASCICUL

The arrangement of the fasciculi (or "fibres," as they are ordi in the auricles and ventricles must be considered separately, for bundles of the two are not continuous, being only connected by th around the auriculo-ventricular orifices: in conformity with this after boiling the heart, the auricles may be easily separated from t

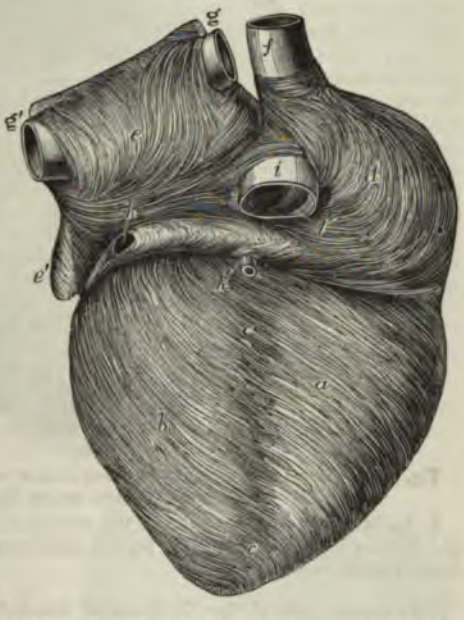
Fibres of the auricles.—These consist of a superficial set, c cavities, and of deeper fibers proper to each. The *superficial fi* versely over both venous sinuses, and are most numerous o surface; some pass in at the inter-auricular septum (fig. 431). fibres, which are proper to each auricle, some pass over the auric be attached by both extremities to the corresponding auriculo-ve (*looped fibres*). Others, which are termed *annular fibres*, encircl appendages (fig. 431 *d'*, 431 *e'*), some longitudinal fibres runnin Annular fibres also surround the entrances of the venæ cavæ (*f*, and of the coronary vein and the pulmonary veins on the left si (*g*, *h*),—the muscular fibres extending for some distance from t

especially upon the superior vena cava and the pulmonary veins. The
s in the septum is also encircled by annular fibres.

of the ventricles.—The muscular fasciculi of the ventricles have a
ate disposition, which has received great attention from anatomists.
he statements, however, are conflicting, and it must be confessed that
still admits of further investigation.*

s on the outer surface of the ventricles (figs. 431, 432, *a*, *b*) extend from
here they are attached to the tendinous structures around the orifices,
e apex of the heart, where they pass with an abrupt twist into the interior

Fig. 432.



-POSTERIOR VIEW OF
ME PREPARATION AS
SENTED IN THE PRE-
VIOUS FIGURE (Allen Thom-

ventricle ; *b*, left
c, posterior interven-
oove, from which the
essels have been re-
right auricle ; *e*, the
perior vena cava ; *g*,
ary veins cut short ;
of the great coronary
ed by muscular fibres ;
r coronary vein joining
ipal one ; *i*, inferior
; *v*, Eustachian valve.

eft ventricle. Their
rection is not vertical
ie, especially in front
just as if while the
organ remained fixed
ad been twisted half
the direction of the
the hands of a watch.
a distinct thin super-
um, best marked at the
he right ventricle, for
direction of the fibres is quite different from those immediately beneath.
ack they pass over the septum without turning in : at the front they
what interrupted by fibres which come out from the septum ; except
he base and apex, where they cross uninterruptedly from one ventricle
ier (fig. 433).

uperficial fibres be traced into the interior of the left ventricle at the apex,
l that they pass for the most part into continuity with the papillary mus-
the adjacent parts of the inner layer of muscular fibres of that cavity.
hose which are seen crossing over the front and left side of the heart can
towards the posterior papillary muscles, whilst those which pass over the
right side of the heart, are chiefly continuous with the anterior papillary
Many of the superficial fibres, however, after gaining the interior of the left
do not pass into the papillary muscles, but spread out as an inner vertical
uscular fasciculi, which pass upwards to be attached to the fibrous rings
e of the ventricle.

uliar spiral concentration of the fibres of the heart at the apex is known
rtex or *whorl*, and is produced, as already described, by the twisting or
ng of the external fibres as they pass to be continuous with those in

nvenience of description in the following account of the course of the fibres,
supposed placed apex downwards, and with the anterior and posterior surfaces
lly occupied by the two ventricles (as represented in figs. 431, 432).

the interior. It has been thought that a similar continuity was the
the base of the heart also, and that few if any of the bundles are attache
tendinous rings. But although it is true that some bundles may turn
the auriculo-ventricular openings, this is by no means general, and mo
muscular fasciculi must be described as being attached to the fibrous a
cartilaginous structures at the base, either directly or through the media
chordæ tendineæ and segments of the valves.

Fig. 433.

Fig. 433.—SURFACE FIBRES OF THE VENTRICLES OF THE HUMAN HEART F
FRONT AND BELOW (Reid).

b, bundle of fibres emerging from the interior of the left ventricle at th
and crossing the lower part of the septum uninterruptedly. At *d* the surfac
somewhat interrupted.

The greater part of the thickness of the wall of the left ventricle
of fibres which are attached above, like those just described, to the fib
at the base. From there they pass obliquely downwards in the posterio
wall and more directly downwards in the anterior wall towards the a

Fig. 434.

Fig. 434.—VIEW OF THE
THE SHEEP'S HEART,
AT THE APEX TO
"VORTEX" (Pettigre

a, *a*, fibres entering the
teriorly at *b*; *c*, *c*, fibr
the apex anteriorly at *d*.

before reaching this th
clined, especially the
fibres, somewhat abruptl
the front of the septu
they enter near its lo
They may now be div
three, sets. (1) Many pass at once obliquely upwards in the sept
attached to the central fibro-cartilage, so that these may be re
forming simple V-shaped muscular loops around the cavity of the
tricle. (2) Others cross in the septum in their passage upwards and p

of the right ventricle, being partly continuous with its posterior
cle. (3) Others again pass nearly horizontally into the posterior
ft ventricle, and take an annular course in it. But many of these
of the left ventricle (which are found about the middle of its
continuous with the deeper fibres of the right ventricle.
entricle so far as regards the arrangement of its muscular fasciculi
d upon as an appendage of the left. Its superficial fibres are
nuous, as we have seen, with the papillary muscles of the left ven-
per fibres also mostly pass into continuity with those of the left
ched above to the fibrous structure encircling the right auriculo-ven-
ie pulmonary apertures, either directly or (in the case of the papil-
indirectly through the chordæ tendineæ they pass towards the
posterior fibres enter this behind and pass forwards in it to the
ft ventricle (as above described under 2); the anterior enter the
t and pass backwards in it, intercrossing with those just mentioned,
r part of the left ventricle; while the middle set of fibres, derived
ie external wall of the right ventricle, enter the lower part of the
e directed upwards in it to be attached to the central fibro-cartilage.
iderable number of fasciculi pass straight across the septum without
and appear to encircle both ventricles. There are besides certain
hich appear not readily assignable to any of those above described:
nce, which encircle the pulmonary orifice, and others which, as
wn, radiate upwards from the base of the anterior papillary muscle
entricle, to be attached to the tendinous structures at the base of the
ly to the pulmonary ring, opposite the two anterior sinuses of Val-

Fig. 435.

W OF A PARTIAL DISSEC-
FIBRES OF THE ANTERIOR
VENTRICLES IN A SHEEP'S
NED TO SHOW THE DIFFER-
OF OBLIQUITY OF THE
Thomson).

and apex the superficial
ayed: in the intervening
more of the fibres have
from above downwards,
reater depth on the left
ight side. a^1, a^1, the
s of the right ventricle;
ie of the left ventricle;
have been removed so as
underneath, which are
e same direction as the
over the left ventricle,
er the right; at 3 some
been removed, but the
ly slightly different; 4,
nular fibres occupying the
hickness of the ventricu-
, internal fibres passing
rds the apex to emerge at
ween *c*, *c*, the anterior
rventricular groove, over
ficial fibres are seen cross-
naining part of the groove, some of the deeper fibres turn backwards
; *d*, the pulmonary artery; *e*, the aorta.

le of the thickness of the ventricular wall the fibres are, as before
and transverse (fig. 435, 4, 4'); but, as Ludwig showed, they pass
adual transition into the diagonal ones nearer the surfaces, so that
into layers which may be effected (with the exception of the

superficial stratum over the right ventricle) must be looked upon as i degree artificial.

The muscular fibres of the heart are cross-striated, but differ f fibres of the voluntary muscles in being constantly branched and to one another so as to form a complete network or spongew reticulating interstices. They are moreover composed in the already described (pp. 135, 136,) of somewhat oblong occa forked cells, cemented together end to end. The interstices betw fibres are filled by connective tissue, with numerous blood- lymphatics, and nerves.

Vessels.—The muscular substance is supplied with blood coronary arteries, the origin and course of which, as well as cardiac veins, are elsewhere described. The smaller branches p into every part of the muscular substance, the capillaries bei numerous and closely arranged. The valves are non-vascular, where muscular tissue occurs in them, as is sometimes found to case in the auriculo-ventricular valves (L. Langer).

The lymphatics (which are found in great number beneath b pericardium and endocardium), are also, as was shown by Schw Seidel, extensively distributed throughout the muscular sub occurring in the form of freely communicating fissure-like between the muscular bundles, and lined by epithelioid cell mode of origin being thus to a certain extent lacunar. Accor Skwartzoff, whose observations were made upon the heart of the dog, and calf, the lymphatics of the ventricles are independent o of the auricles and are chiefly collected into a trunk which lies anterior longitudinal groove, turns to the left around the aor passing between this vessel and the trachea enters the lymphatic g glands which are there situated. From them the lymph passes in right innominate vein. Other of the cardiac lymphatics pass at the reflection of the pericardium and over the parietal layer to the thoracic duct.

Nerves.—The nerves given off by the cardiac plexuses rather small in comparison with the bulk of the heart; they are d partly from the cerebro-spinal and partly from the sympathetic (more especially from the pneumogastric nerve, and from the c and superior thoracic ganglia of the sympathetic nerve).

Nerves of the auricles. From the cardiac plexuses at the b the heart, nerves pass to the auricles and there join a plexus chi non-medullated fibres, which is beset with numerous small grou ganglion-cells. This gangliated plexus lies for the most part i diately beneath the pericardial covering of the auricles, but its bra penetrate into the muscular substance.

In the dog's heart Dogiel found three principal groups of ganglia, vi between the superior cava and the right auricular appendix, another betwe same vein and the root of the aorta, and a third between the root of the and the pulmonary veins. Schklarewski, in different mammals, describes the occurring chiefly in the interauricular septum and in the auriculo-ventri groove. The same is affirmed by Skwartzoff, who, however, found the gr on the auricular plexus to be most numerous over the left auricle, and V states, with regard to the human heart, that it is especially near the orifice the pulmonary veins that they occur in largest number.

Nerves of the ventricles. From the cardiac plexuses at the

nerves are given off which, passing downwards along the ent of the aorta and pulmonary artery, reach the coronary accompanying these in their course form secondary plexuses ft coronary plexuses) around those vessels. From the coronary nerous branches proceed, which pass, for the most part, over of the ventricles under the pericardium, but a few small e directed upwards to join the auricular plexus of nerves. scopic groups of ganglion-cells occur, as was shown by upon the coronary plexuses and also here and there along es for a certain distance.

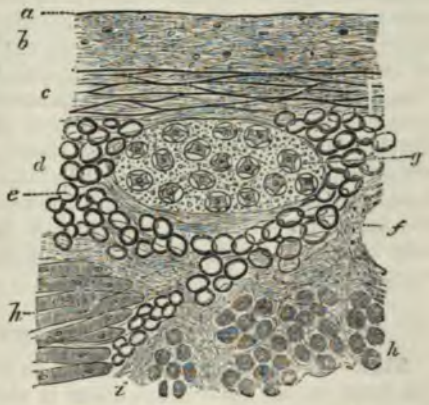
the only nerves which pass to the heart are the cardiac branches ne from each, which reach the heart along the superior venæ cavæ, rsing along the sinus venosus (into the undivided cavity of which their blood) enter the septum between the two auricles. In the erves, now become anterior and posterior, pass down, and at the he auricles with the single ventricle, they each end in a group of , known as the ganglia of Bidder. But along their whole course hey are beset at intervals with small groups of ganglion-cells, and anches in the venous sinus and in the interauricular septum similar ther intercalated in the small nervous cords, or set laterally upon nglion-cells have been proved to occur either on the branches which d to the auricles (with the exception of the septum) or on those the muscular substance of the ventricle.

iac pericardium or **epicardium** has the usual structure of nbrane. It is covered externally by a pavement epithelium

Fig. 436.

CTION OF A PART OF ADIUM OF THE RIGHT A.S.).

ithelium in section; *b*, ue layer; *c*, elastic berous areolar tissue; tion of a blood-vessel; nglion; *h*, muscular nyocardium; *i*, inter- ar tissue.



ly polygonal cells ther serous mem- ata are found here etween these, per- ommunication be- pericardial cavity ymphatics of the Skwartzoff). The the membrane is composed of connective tissue with much e, chiefly collected into a well developed network in the (fig. 436, *c*).

rous areolar tissue is continuous with the interstitial tissue fibres of the myocardium. In it run the vessels and nerves ng down into the muscular substance, and a system of lym- ls, connected with the lymphatic spaces of the myocardium, here. The vessels and nerves are generally imbedded in a

considerable amount of fat (fig. 436, *e*), which is especially in the furrows, but may in fat subjects extend as a layer cov greater part of the surface; and may even be found in t interspaces of the myocardium, and beneath the endocardium.

The **endocardium** furnishes a lining to all the cavities of following the inequalities of the inner surface of the organ, and continuous at the venous and arterial orifices with the inner c

Fig. 437.

Fig. 437. — SECTION OF THE ENDOCARDIUM OF AURICLE.

a, Lining epithelium; *b* tissue with fine elastic fibr with coarser elastic fibres; cardial connective tissue con the intermuscular tissue of dium; *h*, muscular fibres cardium; *m*, plain muscul the endocardium.

respective veins and arteries. A layer of flattened epithelial c and lines the inner surface (fig. 437, *a*), and beneath this cardium consists of connective tissue with a close network fibres often passing into fenestrated membrane. Plain musc are present in some parts (*m*). The ordinary cardiac musc extend in many places close up to the endocardium, but in separated from it by some amount of areolar tissue. In this is often met with, especially in fat subjects and in fatted ani the heart of some animals, as the sheep, large beaded reticula are met with lying in the subendocardial tissue, and, having described by Purkinje, are known by his name. When exam the microscope these fibres of Purkinje are found to be co large clear cells, joined end to end, and containing in their or two nuclei (generally two) embedded in a more granular The periphery of the cells in question is composed of tr striated substance, and they appear to represent a condition o development of cardiac muscular tissue. According to Gegen are occasionally to be found in the human heart. The endoc usually more opaque on the right side than on the left; and the auricles (the left especially) than in the ventricles; it is, very thin on the musculi pectinati of the auricles and on the carneæ of the ventricles.

DIMENSIONS AND WEIGHT OF THE HEART.

Size.—It was stated by Laennec, as the result of his experi the heart in its natural condition is about equal in size to t hand of the individual. It is about five inches long, three a in its greatest width, and two and a half in its extreme thick the sternal to the diaphragmatic surface; but linear measure flaccid organ like the heart must be subject to so many variations as to render them of little value.

Weight.—The weight of the heart in the adult is also considerable variation, ranging between rather wide limits, whi on the general weight of the body and on the sex.

weight is about 9 or 10 oz.

to Reid's tables, the average weight in the adult male is as high as
in the female 9 oz. ; while according to Peacock the average of the
., and that of the female 9 oz. The proportion of the weight of the
of the body is from 1 to 150 to 1 to 170.
wn by Clendinning that the heart continued to increase in weight
anced period of life, but at a comparatively slower rate subsequently
twenty-nine years.
Beneke finds the *volume* of the heart to increase with age, at first
gradually. Thus in the new-born infant the average volume is 22
ctres; at the fifteenth year it is 150 cc. to 160 cc.; and at the
ır about 250 cc. After this it increases but slowly up to the fiftieth
th time it has arrived at 280 cc. Subsequent to this there is a slight
nution. Up to the age of puberty the volume is about the same
, but after puberty it is 25 cc. to 30 cc. larger in the male. On
e obvious difficulties of the investigation these statements can how-
regarded as approximate.
s are generally stated to be rather less capacious than the ventricles.
ricle is also said to be larger than the left, in the proportion of 5 to
r). In the ordinary modes of death, the right ventricle is always
apacious than the left, probably owing to its being distended with
ft ventricle, on the other hand, is found nearly empty, and thus
fully contracted. There are good reasons for believing that during
my difference of capacity exists between the two cavities.
auriculo-ventricular opening, and the orifice of the pulmonary
th found to be somewhat larger after death than the corresponding
he left side of the heart.*

.—On the structure of the heart.—*Weismann*, in Arch. f. Anat., 1861;
how's Archiv, XXXVII.; *Obermaier*, in Arch. f. Anat., 1867; *Lehnert*, in
. Anat., 1868; *Schweigger-Seidel*, article "Heart" in Stricker's Hand-
Colleston, Harveian oration, Brit. Med. Journ., 1873; *Paladino*, Contrib.
re, 1876; *Bernays*, in Morph. Jahrb. II. (valves); *Gegenbaur*, in Morph.
Purkinje's fibres); *Ranvier*, Leçons faites au Collége de France, 1880;
Wiener Sitzungsb., 1880. (on foramina Thebesii and valves).
phatics of the heart.—*Skwartzoff*, in Pflüger's Archiv, VIII.; *Schumkow*,
mphatics of pericardium); *Salvioli*, in Arch. p. l. sci. med., 1878.
es of the mammalian heart.—*Remak*, in Müller's Archiv, 1844; *Skwartzoff*,
el, in Arch. f. mikr. Anat. XIV.; *Schklarewski*, in Göttinger Nachricten,
neys, in the Journ. of Anat., 1879; *Vignal*, in Arch. de physiol., 1881.
ensions and weight of the heart.—*Reid*, in the Lond. and Edin. Monthly
l. Science, April, 1843; *T. B. Peacock*, in the same journal, in 1846, and
ately, with additional observations, in 1854; *Clendinning*, in the Medic.
, 1838; *Beneke*, in Marburger Schriften XI., 1879.
ect of the arrangement of the cardiac fibres may be consulted *C. F. Wolff*,
rum muscularium cordis; Act. Acad. Petropol. 1780—1792; *C. Ludwig*,
für rationelle Medizin, 1849; and Müller's Archiv; *Winckler*, in Archiv
und Physiologie, 1865; *J. Pettigrew*, in Philosoph. Transactions, 1864;
l Anatomy, 1869.

hibiting the weight of the heart at different ages, and also the average
the auriculo-ventricular and arterial orifices, will be found in previous
work.

ORGANS OF RESPIRATION.

Besides the heart, the thorax contains the principal organs of
tion, viz., the lungs and a part of the trachea. The larynx,
affixed to the upper end of the windpipe, and is not only the
for air into the respiratory organs from the pharynx, but also t
of voice, will be described after the lungs.

THE LUNGS.

The *lungs* occupy by far the larger part of the cavity of the c
during life are always in accurate contact with the internal s
its wall. Each lung is attached at a comparatively small pa
flattened inner or median surface by a part named the *root*.
directions the lung is free and its surface is closely covered by
membrane, which is reflected at the root to the corresponding si
thorax, and named the (right or left) *pleura*.

THE PLEURÆ.

The **pleuræ** are quite distinct from each other. Each cons
visceral and a *parietal* portion. The visceral portion, *pleura pu*
covers the lung ; and the parietal portion lines the ribs and in
spaces, *pleura costalis*, covers the upper convex surface of the di
enters into the formation of the mediastinum, and adheres to th
the pericardium.

At the root of each lung the visceral and parietal portion
corresponding pleura are continuous with one another ; and
lower border of the root, is a fold of the serous membrane, c
vertically along the inner surface of the lung down to the diaph
which it is attached by its extremity ; this fold is named *lig*
latum pulmonis.

Along the inner border of each lung there descends a ligamentous
offshoot of the prevertebral fascia, attached above to the bodies of th
and first dorsal vertebræ and below to the pericardium and central tend
diaphragm. These bands, the "suspensory ligaments of the diaphr
Teutleben, embrace the roots of the lungs, and in a measure serve to
these and the other parts to which they are attached below.

The upper part of the pleura, together with the apex of
responding lung, rises into the root of the neck, reaching fro
two inches above the anterior end of the first rib (half an inc
and a half inches above the clavicle, Pansch), and passing up un
of the scaleni muscles. Anteriorly the pleural sacs of opposite s
nearly or altogether into contact behind the second piece of the
and continue so for some distance ; but opposite the lower en
sternum the right pleura passes beyond the middle line or rem
to it, while the left recedes to a variable distance. Inferiorly t
do not pass quite down to the attachments of the diaphragm, b
portion of its circumference in contact with the costal parietes
to the height of the diaphragm on the right side (corresponding

nvexity of the liver), the right pleural sac is shorter than the
s at the same time wider. Behind, the lower extent of the
as far down as the vertebral end of the twelfth rib, or even
cases as far as the transverse process of the first lumbar
In the line of the axilla, the right pleura extends down to the
e of the ninth rib, while the left pleura reaches to the lower
e tenth (Luschka). In front the right pleura reaches down
ıction of the seventh rib with its cartilage; the left pleura a
r.

lip of muscle arising from the transverse process of the last cervical described by Sibson as expanding into a dome-like aponeurosis or ch covers or strengthens the pleural cul-de-sac, and is attached to the e inner edge of the first rib.

ure.—The pleura possesses the usual characters of serous mem-
The costal part is the thicker, and may be easily raised from
nd intercostal spaces. It is strengthened here by a layer of
areolar tissue of considerable thickness. On the pericardium
ragm the pleura is thinner and more firmly adherent; but it is
nd least easily detached upon the surface of the lungs. A
is also noticeable in the character of the superficial epithelial
· while on the *pleura costalis* this consists of the ordinary
cells, on the *pleura pulmonalis* the cells are less distinctly
and more granular and polyhedral, but they become flat-
when the lung is distended (Klein). Lymphatic vessels are
in and beneath the pleura as in other serous membranes,
communicate in many parts, by means of stomata, with
r of the membrane. In the *pleura costalis* the stomata
found over the intercostal spaces not over the ribs
ky).
ı the serous covering there is placed a thin layer of *subserous*
sue mixed with a large number of elastic fibres. It is con-
ith the areolar tissue in the interior of the lung, and has been
as a distinct coat under the name of the second or deeper layer
ıra. In the lungs of many animals, such as the lion, seal, and
nis subserous layer forms a very strong membrane, composed
r of elastic tissue; in others, as the guinea-pig, a network of
cular fibres is found which have a general radiating direction
pex (Klein). A close plexus of lymphatic vessels is also met with
›-pleural tissue: these vessels communicate on the one side by
stomata with the pleural cavity, and on the other, as will be
ı noticed, with a network of similar vessels in the inter-alveolar
ıe lungs. A uniform network of capillary blood-vessels covers
e of the lung. These are supplied from branches of the bron-
ies. They are less closely arranged than the blood-vessels of the
r alveoli, and are thus as well as by their position easily dis-
ıle from them in specimens of injected lung.

THE LUNGS.

ıng is irregularly pyramidal or conical, with the base down-
. 438). The broad, concave *base* is of a semilunar form, and
ı the arch *of the diaphragm. It is* bounded by a thin margin,

which is received in the angle between the ribs and the diaphra reaches much lower down behind and at the outer side than in fro *apex* is blunt, and, as already mentioned, reaches into the ro neck, above the first rib, where it is separated from the first p the subclavian artery by the pleural membrane. The apex is marked by a groove where the subclavian artery crosses it. *surface*, which moves upon the thoracic parietes, is smooth, co of great extent, corresponding with the arches of the ribs a cartilages. The *inner surface* is concave, and in part adapte convex pericardium. The *posterior* border is rounded, and is into the deep groove formed by the ribs at the side of the column ; measured from above downwards, it is the longest pa lung. The *anterior* border is thin and overlaps the pericardium, a sharp edge, which, opposite the middle of the sternum, is during inspiration from the corresponding margin of the oppo only by the two thin layers of the mediastinal septum. Upon surface, somewhat above the middle of the lung, and considerab

Fig. 438.

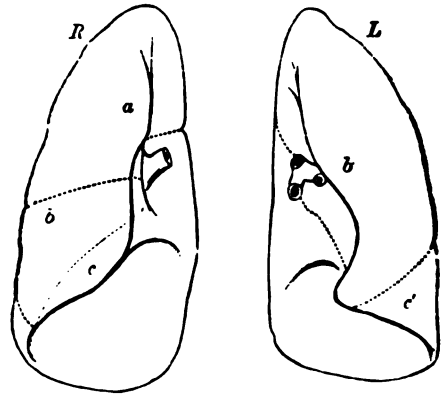


Fig. 438.—Outline of the lungs from before (after His). ½

R, right lung ; *L*, left lung ; *a*, *b*, *c*, upper, middle, and lower lobe of *b'*, *c'*, upper and lower lobes of left lung. The fissures are indicated by dotte

to the posterior than the anterior border, is the *root*, where th and great vessels join the lung.

The left lung is divided into two lobes by a long and de which penetrates obliquely upwards and inwards from the out to within a short distance of the root. The *upper lobe* is th and is irregularly conical, with an oblique base and rounded ap the *lower* is quadrilateral. In the right lung there are tw which pass the one from above the middle of the external su the other from near its lower end, and converge towards the marking off three lobes, an *upper*, *middle*, and *lower*. Of the tw the upper is less extensive than the lower, and in consequence, t

h is usually much smaller than the others, appears at first
more closely connected with the upper lobe, and is usually
s forming a part of it.

however, of its comparatively small size, it appears not improbable,
searches of Aeby, which will be afterwards more fully referred to,
iddle lobe of the right lung is the morphological equivalent of the
lobe of the left lung.

lung has a deep notch in its anterior border, into which the
e heart (enclosed in the pericardium) is received. Besides
rences the right lung is shorter than the left, owing to the
rising higher on the right side to accommodate the liver,
left lung is the narrower, owing to the heart and pericardium
g on the left half of the thorax. On the whole, however, as
a comparison of their weights, the right is the larger of the

summits and posterior borders the extent of the lungs cor-
ith that of the pleural sacs which contain them, but in front
the relation is variable, inasmuch as the anterior margins
rds most completely between the mediastinal and costal
ing inspiration, and retire to a variable degree from between
piration; and in like manner the inferior margins descend,
spiration, between the costal and diaphragmatic pleurae;
t no time do they ever descend completely to the line of
etween those membranes.
t of each lung is composed of the bronchus or sub-division of
e, and the large blood-vessels, together with nerves, lymphatic
d glands, connected together by areolar tissue, and enclosed
ection of the pleura.
t of the right lung lies behind the superior vena cava and
right auricle, and below the azygos vein, which arches over
the superior cava. That of the left lung passes below the
aorta, and in front of the descending aorta. The phrenic
ends in front of the root of each lung, and the pneumogastric
nd, whilst the ligamentum latum pulmonis is continued from
border. The bronchus, together with the bronchial arteries
the lymphatics and lymphatic glands, are placed on a plane
o the great blood-vessels, whilst the pulmonary veins are in
he arteries. The pulmonary plexuses of nerves lie on the
nd posterior aspect of the root, beneath the pleura, the
lexus being the larger of the two.
right side the undivided portion of the bronchus is altogether
right pulmonary artery, on the left side the undivided portion
nchus, which is considerably longer than on the right side,
below the level of the left pulmonary artery which crosses
oth sides the pulmonary veins are below the corresponding

ntering the substance of the lung, the right bronchus gives off
a to the upper lobe, and is then continued on into the lower
anch for the middle lobe being given off from the continuation.
sponding branch of the left bronchus is considerably larger,
the upper *lobe of its lung*. The main branches of the

combined weight of the two at 42 ounces. The lungs are absolutely heavier in the male than in the female, but ap heavier in proportion to the weight of the body.

According to the observations of Reid the average weight in 29 found to be 24 oz. for the right lung, and 21 oz. for the left; and in 17 oz. for the right, and 15 oz. for the left lung.

Physical properties.—The substance of the lung is porous spongy texture, and, when healthy, is buoyant in wat the fœtus, before respiration has taken place, and also in ce of congestion, collapse, or consolidation from disease, the en or portions of them, sink in that fluid. The specific gr healthy lung, as found after death, varies from 0·345 to 0·74 the lung is fully distended its specific gravity is 0·126, whil the pulmonary substance, entirely deprived of air, is 1·056 When pressed between the fingers, the lungs impart a sensation, which is accompanied by a peculiar noise, both eff caused by the air contained in the tissue. On cutting lung, the same crepitation is heard, and there exudes fro surface a reddish frothy fluid, which is partly mucus from tubes and air-cells, and partly serum of blood, rendered frot admixed air.

The pulmonary tissue is endowed with great elasticity, quence of which the lungs collapse to about one-third of t when the thorax is opened. Owing to this elasticity also, th artificially inflated out of the body, contract to their previo when the air is again allowed to escape.

In infancy the lungs are of a pale rose-pink colour, which compared to blood-froth; but as life advances they become d are mottled or variegated with spots, patches, and streaks of colour, which sometimes increase to such a degree as to render t almost uniformly black.

ion in the fœtus and changes after birth.—In the fœtus contain no air, and consequently sink in water. They undergo . and remarkable changes after birth, in consequence of the ment of respiration: these affect their size, position, form, e, texture, colour, and weight, and should be carefully studied, ing the only means of distinguishing between a still-born child at has respired.

on, *size, and form.*—In a fœtus at the full period, or in a still-born lungs, comparatively small, lie packed at the back of the thorax, ; entirely cover the sides of the pericardium; subsequently to respi- y expand, and completely cover the pleural portions of that sac, o in contact with almost the whole extent of the thoracic wall, is covered with the pleural membrane. At the same time, their thin sharp margins become more obtuse, and their whole form is less

tence, texture, and colour.—The introduction of air and of an increased f blood into the fœtal lungs, which ensues immediately upon birth, eir tissue from a compact, heavy, granular, yellowish-pink, gland-like into a loose, light, rose-pink, spongy structure, which, as already men- ats in water. The changes thus simultaneously produced in their , colour, and texture, occur first at their anterior borders, and proceed through the lungs: they, moreover, appear in the right lung a little a in the left.

t.—The *absolute weight* of the lungs having gradually increased from t period of development to birth, undergoes at that time, from the f blood then poured into them, a very marked addition, amounting to one third of their previous weight: for example, the lungs before a about one and a half ounce, but after complete expansion by respi- y weigh as much as two and a half ounces. The *relative weight* of the e body, which at the termination of intra-uterine life is about 1 to 70, fter respiration, on an average, about 1 to 35 or 40; a proportion ot materially altered through life. The *specific gravity* is at the same ed from 1·056 to about ·342.

THE TRACHEA AND BRONCHI.

achea or **windpipe** (fig. 439, *tr.*), the common air-passage of s, is an open tube which commences above at the larynx, and elow into two smaller tubes, right and left bronchi, one for

achea is placed in the median plane of the body, and extends lower border of the cricoid cartilage of the larynx (*c*), on a the 6th cervical vertebra in the neck, to a place opposite the een the 4th and 5th dorsal vertebræ in the thorax, where it in front by the arch of the aorta, and at or immediately below t bifurcates into the two bronchi. It usually measures from es to four inches and a half (10 to 11 centimeters) in length, three-quarters of an inch to one inch (2 to 2½ centim.) in ut its length and width are liable to much variation, according sition of the larynx and the direction of the neck; moreover, lly increases in calibre from above downwards (Aeby). Its liameter is greater in the male than in the female. In front he sides the trachea is rendered cylindrical, firm, and resistant, es of cartilaginous rings; these, however, are deficient behind.

so that the posterior portion is flattened and entirely me
(fig. 440). Near its bifurcation the trachea is somewhat
laterally.

In the fœtus the trachea is flattened before and behind, its anter
being even somewhat depressed; the ends of the cartilages touch; an
of the tube, which now contains only mucus, are applied to one ano
effect of respiration is at first to render the trachea open, but it sti
somewhat flattened in front, and only later becomes convex.

Relations of the trachea to neighbouring parts.—The
is nearly everywhere invested by a loose areolar tissue, abounding

Fig. 439.

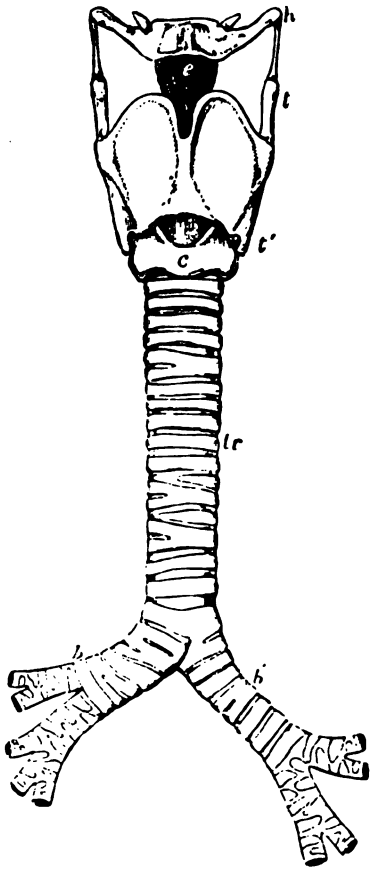


Fig. 439.—Outline showing
ral form of the larynx
and bronchi, as seen fr
(Allen Thomson). ½

h, the great cornu of the
e, epiglottis; *t*, superior, and
cornu of the thyroid cartilage
of the cricoid cartilage; *t r*,
showing sixteen cartilaginou
the right, and *b'*, the left bro
this and also in the succeedin
right bronchus is represented
horizontal (see p. 510 and fig

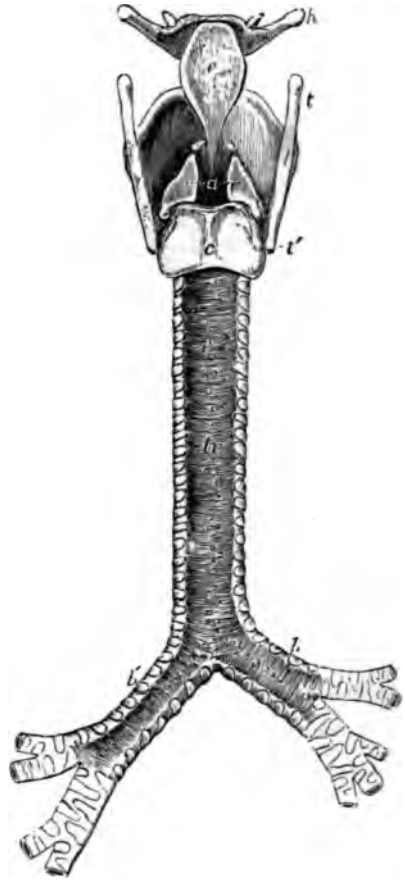
fibres, and is very moveal
surrounding parts. Bot
neck and thorax, it rest
against the gullet, whi
venes between it and the
column, but towards i
part projects somewha
left side. The recurrent l
nerves ascend to the la
each side in the angle
these two tubes.

In the neck the tr
situated between the
carotid arteries; at its u
it is embraced by the
lobes of the thyroid b
middle part or isthmus
lies across it just be
larynx. It is covered
by the sterno-thyroid an
hyoid muscles, betwee
however, there is left
gated lozenge-shaped in
the middle line: this interval is covered in by a strong process of
cervical fascia, while, more superficially, another layer not
crosses between the sterno-mastoid muscles. The inferior thyr
and the *arteria thyroidea ima*, when that vessel exists, also lie

face ; whilst at the root of the neck, in the episternal notch, ate artery and the left carotid pass obliquely over it as they in its sides.

horax, the trachea is covered by the manubrium sterni, th the sterno-thyroid and sterno-hyoid muscles; lower he left innominate vein, then by the commencement of ate artery and left carotid, which pass round to its sides; y the arch of the aorta and the deep cardiac plexus of nerves. een the two pleuræ, the trachea is contained in the supe- tinum, and has on its right side the pleura and pneumo- e, and on the left, the left carotid artery, the pneumo-gastric rrent branch, together with some cardiac nerves.

Fig. 440.



PLINE SHOWING THE GENE- F THE LARYNX, TRACHEA, I, AS SEEN FROM BEHIND son). ½

nu of the hyoid bone; *t*, *t'*, inferior cornu of the ge; *e*, the epiglottis; *a*, ack of both the arytenoid ch are surmounted by the the middle ridge on the ricoid cartilage; *t r*, the ranous part of the trachea; l left bronchi.

t and left bronchi 40, *b*, *b'*) proceed each of the corresponding hen undergo division. o this they exactly e trachea on a smaller g rounded and firm d at the sides, where ovided with imperfect s rings, and flattened ranous behind. The portion of the right), wider but shorter ft, measuring about an centim.) in length, uely downwards and nto the root of the it is embraced above azygos, which hooks er it, to end in the superior; the right artery lies at first d then in front of it. down the windpipe towards the bifurcation, the right pears to be a more direct continuation of the trachea than the undivided portion of the left bronchus (*b'*), smaller in

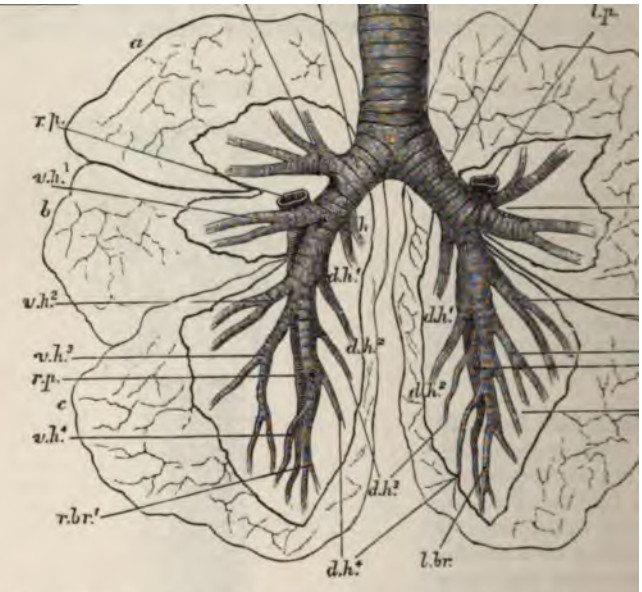


Fig. 441.—SKETCH SHOWING THE LOWER END OF THE TRACHEA, ITS DI
TWO BRONCHIAL TRUNKS, AND THE COURSE AND CHIEF BRANCHES O
THE LUNGS, FROM BEFORE (after Aeby).

a, upper ; *b*, middle ; *c*, lower lobe of the right lung ; *b'*, upper ; *c'*,
left lung ; *r.p.* right pulmonary artery ; *l.p.* left artery ; *r.br.* right
l.br. left bronchial trunk ; *ep*, on the right side, eparterial branch sup
lobe ; *v.h.*¹, first ventral hyparterial bronchus supplying the middle l
side, the upper lobe on the left ; *v.h.*², *v.h.*³, *v h.*⁴, the remaining v
branches distributed in the lower lobe on each side ; *d.h.*¹, *d.h*², *d.h.*
dorsal hyparterial branches distributed on both sides in the posterior and

together by a strong fibrous membrane, which is elastic and yiel to a certain extent, and not only occupies the intervals between t but is prolonged over their outer and inner surfaces, so that they ar it were, imbedded in the membrane.

The cartilages terminate abruptly behind by rounded ends, but

Fig. 442.

Fig. 442.—LONGITUDINAL SECTION OF THE HUMAN TRACHEA, INCLUDING PORTIO TWO CARTILAGINOUS RINGS (Klein and Noble Smith). MODERATELY MAGNIFIED.

a, ciliated epithelium; *b*, basement membrane; *c*, superficial part of the mu membrane, containing the sections of numerous capillary blood-vessels and much lymp tissue; *d*, deeper part of the mucous membrane, consisting mainly of elastic fibre submucous areolar tissue, containing the larger blood-vessels, small mucous glands (t ducts and alveoli are seen in section), fat, &c.,; *f*, fibrous tissue investing and uni the cartilages; *g*, a small mass of adipose tissue in the fibrous layer; *h*, cartilage.

fibrous membrane is continued across between them, and completes t tube behind; it is here looser in its texture.

The first or highest cartilage, which is connected by the fibrous membrane wi the cricoid cartilage of the larynx, is broader than the rest, and often divided at o end. Sometimes it coalesces to a greater or less extent with the cricoid or wi the one below. The lowest cartilage, placed at the bifurcation of the trachea, peculiar in shape; its lower border being prolonged downwards, and at the sam time bent backwards so as to form a curved projection between the two bronch The cartilage next above this is slightly widened in the middle line. Sometim the extremities of two adjacent cartilages are united, and not unfrequently a ca tilage is divided at one end into two short branches, the opposite end of th next it being likewise bifurcated so as to maintain the parallelism of the ent

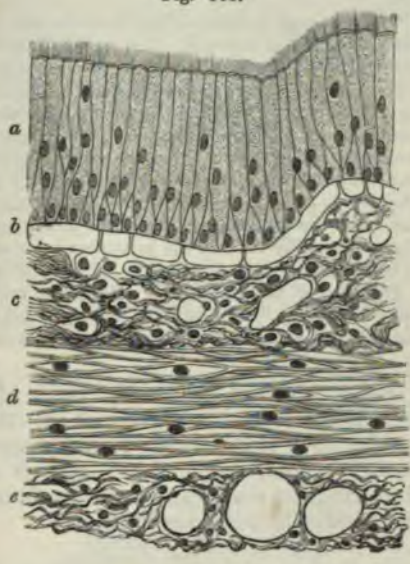
use of these cartilaginous hoops is to keep the windpipe open, a con-
al for the free passage of air into the lungs.

he fibrous membrane at the posterior flattened part of
, is a continuous pale reddish layer of *unstriped mus-*
, which pass across, not only between the ends of the
ut also opposite the intervals; they doubtless serve to narrow
approximating the ends of the cartilages. Those opposite
e attached to the extremities of the latter, and encroach also
distance upon their inner surface. Outside the transverse
few fasciculi having a longitudinal direction.

PART OF THE SECTION
IN THE PRECEDING
E HIGHLY MAGNIFIED
Coble Smith).

epresent the same parts
e.

Fig. 443.



nucous tissue con-
ose areolar tissue
s to connect the
mbrane with the
r and the cartila-
gs. It contains
ds and a quantity
ssue is often found

cous membrane is smooth and of a white colour in ough when con-flamed, it becomes rple or crimson. It nsiderable amount l tissue. Under-ithelium is a basement membrane (fig. 443, *b*), well marked an trachea, through which processes from the subjacent tissue cells and cell-spaces here and there pass into the Throughout the mucous membrane a number of fine elastic nd, but in the deeper parts the elastic fibres are very large us (*d*). Along the posterior membranous part, they are nt than elsewhere, and are there collected into distinct longi-dles, which produce visible elevations or flutings of the brane. These bundles are particularly strong and numerous bifurcation of the trachea.

elium consists of a layer of columnar ciliated cells, often ar at their fixed end, where they are impressed by smaller n which they penetrate to reach the basement membrane. erve to drive the mucous secretion upwards towards the tween these ciliated cells, are found others, some rounded ated; the latter being prolonged at one end towards the st the other end, which is not unfrequently forked, reaches acent membrane. *A few lymph* corpuscles are also found

amongst the epithelial cells, as in other epithelia. Some of the ... secrete mucus, and hence goblet-cells are frequently found here ... p. 44).

The trachea is provided with numerous small *mucous glands*. ... largest are situated at the back part of the tube, either close upon ... outer surface of the fibrous layer, or occupying little recesses ... between its meshes. Smaller glands are found between the cartilag... rings, upon and within the fibrous membrane, and still smaller ones ... beneath the mucous membrane. They are compound glands, and ... cavities are lined by a columnar or cubical epithelium: the ... ducts pass through the muscular layer and the mucous membrane ... the surface of which their orifices are perceptible.

Vessels and Nerves.—The *arteries* of the trachea are principally ... from the inferior thyroid. The larger branches run for some distance ... nally, and then join a superficial capillary plexus with polyhedral meshes. ... *veins* enter the adjacent plexuses of the thyroid veins. A rich plexus of ... may readily be injected in the mucous membrane and submucous tissue, ... lymphoid follicles, so common in the alimentary mucous membrane, and ... the walls of the smaller bronchi, are rarely present. When found it is ... surrounding the ducts of the glands as they pass through the mucous membrane. The *nerves* come from the trunk and recurrent branches of the pneumo-gastric and from the sympathetic system. There are said to be numerous ganglia upon them, especially outside the muscular layer at the back of the tube. Their mode of termination has not yet been satisfactorily traced.

In the dog, cat, sheep, and rabbit, the upper half of the trachea is said to be supplied chiefly by the superior laryngeal nerve, through the anastomosis between the superior and inferior nerves in the larynx (Kandarazi).

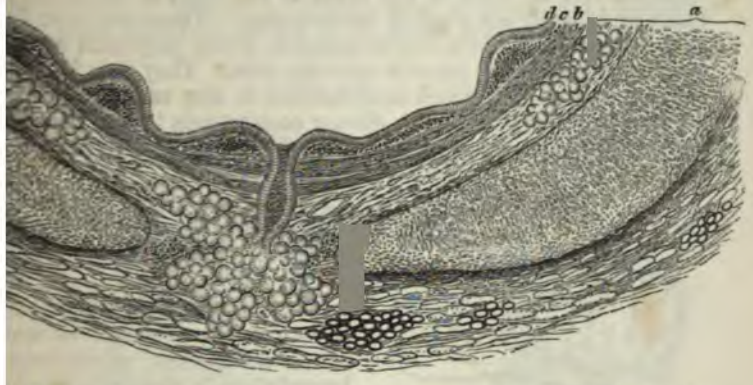
Bronchi.—The general structure of the undivided portions of the bronchi corresponds with that of the trachea in every particular. The cartilaginous rings, which resemble those of the trachea in being imperfect behind, are, however, shorter and narrower. The number of these rings on the right side varies from six to eight, whilst on the left the number is from nine to twelve.

The bronchi are supplied by the bronchial arteries and veins, and the nerves are from the same source as those of the lower part of the trachea.

Termination of the bronchi; structure of the bronchial tubes. The principal divisions of the bronchi, as they pass into the lungs, divide into tubes of less calibre, and these again subdivide in succession into smaller and smaller tubes, often distinguished as *bronchia*, *bronchioles*, or *bronchial tubes*, which, diverging in all directions, never anastomose, but terminate separately. The larger branches diverge at acute angles, but the more remote and smaller ramifications spring less acutely. After a certain stage of subdivision each bronchial tube, reduced to a small size (about 1 mm.), is termed a *lobular* or *respiratory bronchial tube* (Kölliker), and its walls become beset with small hemispherical saccules, termed *air-cells*, or *alveoli*. They occur at first only here and there and confined to one side of the tube only, but at length almost cover it so that the tube in great measure loses its cylindrical character. At length it ends in an enlarged completely sacculated passage termed the *alveolar passage*, from which are given off blind ramifications,

at enlarged towards their extremities, and everywhere closely
vith the air-cells. These enlarged terminations are named
ula (fig. 446).

Fig. 444.



—PORTION OF A TRANSVERSE SECTION OF A BRONCHIAL TUBE, HUMAN (6 MM. IN DIAMETER) (F. E. Schultze). MAGNIFIED 30 DIAMETERS.

lage and fibrous layer with mucous glands, and, in the outer part, a little fat; ddle, the duct of a gland opens on the inner surface of the tube; *b*, annular voluntary muscular fibres; *c*, elastic layer, the elastic fibres in bundles which ut across; *d*, columnar ciliated epithelium.

in the lungs the air-tubes are not flattened behind like the bronchi chea, but form completely cylindrical tubes. Hence, although

Fig. 445.

5.—SECTION OF A SMALL BRONCHIAL TUBE (4 MM. IN DIAMETER) FROM THE PIG'S LUNG (F. E. Schultze). MAGNIFIED 240 DIAMETERS.

us layer; *b*, muscular layer; *c*, mucous membrane in longitudinal folds, with longitudinally running elastic fibres cut across; *d*, ciliated epithelium; *f*, sur- alveoli.

they contain the same elements as the larger air-passages, they are re
gradually to a state of greater tenuity, but possess certain peculi
of structure. Thus, the *cartilages* no longer appear as imperfect
running only upon the front and lateral surfaces of the air-tube, b
disposed over all sides of the tubes in the form of irregularly s
plates and incomplete rings of various sizes. These are most deve
at the points of division of the bronchia, where they form a sharp
cave ridge projecting inwards into the tube. They may be trace
coming rarer and rarer and more reduced in size, as far as bronchi
millimeter in diameter. The *fibrous* coat extends to the smallest t
becoming thinner by degrees and degenerating into areolar tissue

Fig. 446.

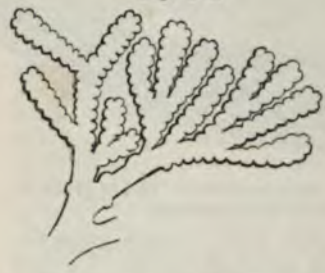


Fig. 446.—DIAGRAMMATIC REPRESENTATI
THE TERMINATION OF A BRONCHIAL TU
GROUP OF INFUNDIBULA. (E.A.S.)

it are mucous glands which send
ducts to open on the mucous memb
These occur most numerously i
larger tubes; in those which measur
than 1 mm. they are rarely if
found. The *mucous membrane*,
extends throughout the whole syst
air passages, is also thinner than i
trachea and bronchus, but it retains its ciliated columnar epith
(figs. 444, 445, *d*). The longitudinal bundles of *elastic* fibres (*c*, i
transverse sections) are very distinct in both the large and
bronchia, and may be followed by dissection as far as the
can be laid open, and by the microscope into the smallest tubes.
muscular fibres, which in the trachea and bronchi are confine
the back part of the tube, surround the bronchial tubes with a
tinuous layer of annular fibres, lying inside the cartilaginous p
(*b*); they are found, however, beyond the place where the carti
cease to exist, and appear as irregular annular fasciculi even in
smallest tubes.

STRUCTURE OF THE PULMONARY PARENCHYMA.

At the point where the small bronchial tubes lose their cylind
character, and begin to be beset with air-cells, their structure
gradually undergoes a change. The muscular layer almost disap
the longitudinal elastic bundles are broken up into an interlacem
areolar and elastic tissue, which surrounds the mouths of the air
and the walls of the infundibula, and the columnar ciliated epith
gives place to a stratum of non-ciliated cells. The change i
character of the epithelium first occurs in the so-called respi
bronchioles, where patches of small pavement epithelium-cells be
appear amongst the ciliated cells, especially in the neighbourhood
air-cells upon the wall of these tubes. At the end of the respi
bronchiole, near the passage to the infundibula, all the cells whi
the wall of the tube are of the non-ciliated pavement variety. B
air-cells themselves, both those which are scattered over the respi
bronchioles and those which cover the infundibula, as well as in
diate portions of the infundibula which occur here and there betwe

lls, possess an epithelium of a peculiar character. The cells of epithelium are of two kinds, viz. :—1, large, thin, very delicate irregular in size and shape, lying over the blood-vessels, but in many cases extending over the interstices between them; appear not to possess a nucleus: and, 2, small, flat, polygonal, ated cells, which lie singly or in small groups of two or three

Fig. 447.

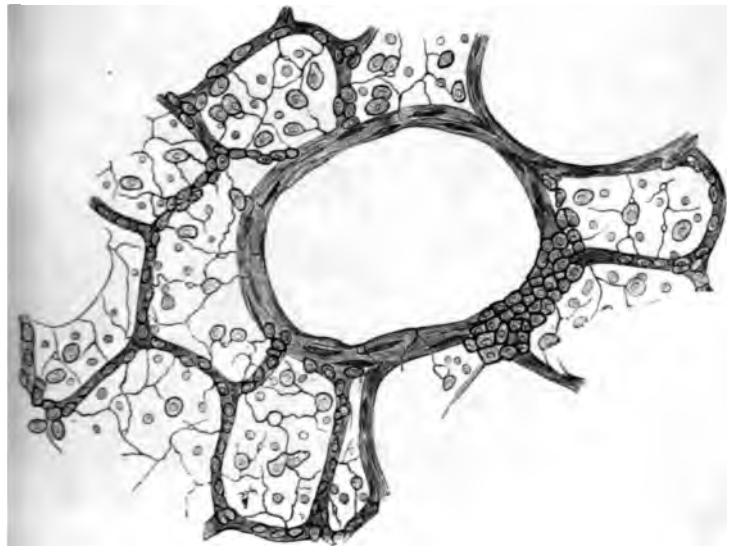


Fig. 447.—Section of part of cat's lung, stained with nitrate of silver (Klein and Noble Smith). Highly Magnified.

he small granular and the large flattened cells of the alveoli are shown. In the middle section of a lobular bronchial tube, with a patch of the granular pavement epithelium on one side.

ls, between the others, and always in the interstices of the capillary work.

n the fœtus the alveoli are entirely lined with small granular pavement cells, with the distension which follows upon the first respiratory efforts most of cells become transformed into the large thin epithelial elements above ribed.

The walls of the alveoli, which mainly consist of an indistinctly llated connective tissue with corpuscles scattered here and there, supported and strengthened by scattered and coiled elastic fibres, cially numerous near their orifices, in addition to which, according Koleschott and others, there is likewise an intermixture of muscular -cells. A number of granular rounded amœboid cells are usually to ound free in the air-cells and smaller bronchial tubes: not unfre-ntly they contain carbonaceous particles. By the migration of these into the pulmonary tissue, the carbon particles may be conveyed the *substance of the lung* and thence into the lymphatics and

bronchial glands, but fluids and fine particles can also, it is bel penetrate directly to the lymphatics, both of the interalveolar tiss of the bronchial tubes, by aid of the pseudostomata which conne cell-spaces of the connective tissue with the inner surface of the m membrane (see p. 521).

The air-cells in the natural state, are always filled with air. They are seen on the surface and in a section of a lung, which has been inflated w and dried; also upon portions of fœtal or adult lung injected with me

Fig. 448.

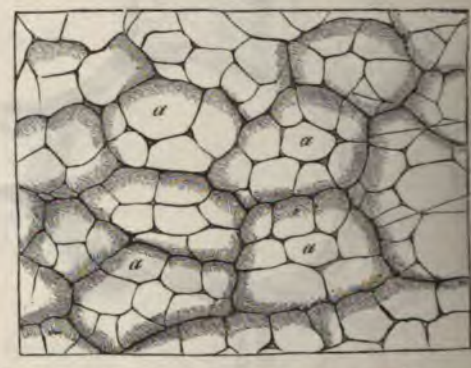


Fig. 448.—Portion of the outer surface of the cow's lung (from Ki after Harting). Magnified 30 diameters.

a, pulmonary vesicles filled artificially with wax; *b*, the margins of the lobules or infundibula.

wax (fig. 448, *a*, *a*). In the lungs of some animals, as of the lion, dog, they are very large, and are distinctly visible on the surface organ. In the adult human lung their most common diameter is ab of an inch (0·25 mm.), but it varies from $\frac{1}{150}$th to $\frac{1}{70}$th of an inch; larger on the surface than in the interior, and largest towards the th of the organ: they are also very large at the apex of the lung. Their dia go on increasing from birth to old age, and they are larger in men than in In the infant the diameter is usually under $\frac{1}{200}$th of an inch.

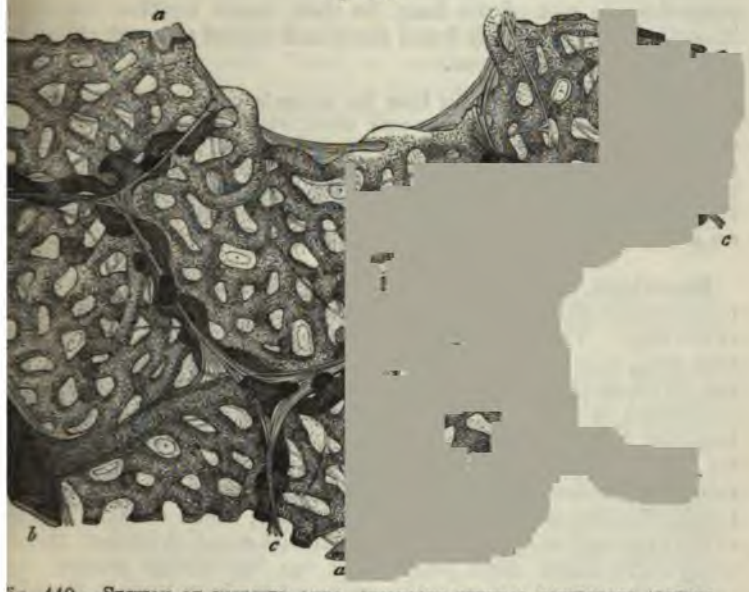
The whole lung has a lobulated structure best seen in the fœtus, w lungs, not yet distended with air, present very much the appearance pound racemose glands. The infundibula may be regarded as corresp the smallest or ultimate lobules of such a gland. They produce the ap of polygonal areas enclosing groups of six or eight air-cells which ar the surface of the lung (fig. 448). The infundibula are grouped into secondary lobules, and these again into yet larger divisions. The vario are united and separated by connective tissue in variable amount, more the larger and less between the smaller groups. From the mutual comp which they are subjected the lobules are bounded by flattened sides, and compactly fitted to each other and to the larger air-tubes and vessels of

BLOOD-VESSELS, LYMPHATICS, AND NERVES OF THE LU

Pulmonary vessels.—The branches of the pulmonary arter pany the bronchial tubes, but in their remote ramifications t divide more frequently. The main arterial trunk runs down imm behind the main bronchial trunk, giving off corresponding bro

ceeds. They ramify without anastomoses, and at length terminate all arteries about $\frac{1}{1000}$th of an inch in diameter, which lie between lveoli, partially encircling their mouths (fig. 449, *b*). From these ls the capillary network arises, and covers each alveolus, passing in nter-alveolar septa between the adjacent air-cells. As was pointed

Fig. 449.



ig. 449.—SECTION OF INJECTED LUNG, INCLUDING SEVERAL CONTIGUOUS ALVEOLI (F. E. Schultze). HIGHLY MAGNIFIED.

a, free edges of alveoli; *c*, *c*, partitions between neighbouring alveoli, seen in on; *b*, small arterial branch giving off capillaries to the alveoli. The looping of essels to either side of the partitions is well exhibited. Between the capillaries is the homogeneous alveolar wall with nuclei of connective tissue corpuscles, and ic fibres.

by Rainey, the capillary network in these partitions is single in the s of man and mammalia, although it forms a double layer in the s of amphibia and reptiles.

he capillaries are very fine, and the network they form is so close the meshes are scarcely wider than the vessels themselves. They ery superficial, being covered only by the thin layer of tesselated elium above mentioned, and in the partitions between contiguous li the vessels of the network project on either side in an arched op-like manner into the cavities of the alveoli (fig. 449). The us membrane of the bronchial tubes, especially near the air- is partly supplied with blood from branches of the pulmonary artery· ie radicles of the pulmonary veins arise from the capillary network ie alveoli and from that of the smaller bronchial tubes. The hes of these veins which arise from the infundibula near the ce of the lung, do not accompany the bronchia and arterial branches, re *found to run alone for a certain* distance through the substance of

the organ. They finally either join some deeper vein which accompa a bronchial tube, or they remain superficial, forming a wide-mes plexus near the surface of the lung, finally tending towards the hilu join the larger veins near the root of the lung. The veins from t more deeply lying infundibula form frequent communications, and fin coalesce into large branches, which accompany the bronchial tubes a arteries, coursing as a rule in front of the bronchial tubes, and t proceed to the root of the lung. In their course together through t lung, the artery is usually found above and behind a bronchial tube, w the vein below and in front.

The pulmonary vessels differ from the systemic in regard to their conte inasmuch as the arteries convey dark blood, whilst the veins carry red blo The pulmonary veins, unlike the other veins of the body, are not more capa than their corresponding arteries; indeed, according to Winslow, Santo Haller, and others, they are somewhat less so. These veins have no val Lastly, it may be remarked that, whilst the arteries of different secondary lobu are usually independent, the veins freely anastomose.

Bronchial vessels.—The bronchial arteries and veins, which a much smaller than the pulmonary vessels, carry blood for the nutriti of the lung. The bronchial arteries, from one to three in number fo each lung, arise from the aorta, or from an intercostal artery, and fol the divisions of the air-tubes through the lung. They are ultimate distributed in three ways: (1) many of their branches ramify in th bronchial lymphatic glands, the coats of the large blood-vessels, and t the walls of the bronchial tubes, supplying an outer capillary plexus wi transverse meshes to the muscular coat, and an inner plexus with clo longitudinal meshes to the mucous membrane, which at the extremiti of the bronchial tubes is continuous with that supplied by the pulmona artery; (2) others form plexuses in the interlobular areolar tissu (3) branches spread out upon the surface of the lung beneath the pleur forming plexuses and a capillary network.

A few small branches of the intercostal arteries also pass to the pulmona pleura and surface of the lung through the ligamentum latum pulmo (Turner).

The bronchial veins have not quite so extensive a distribution in th lung as the bronchial arteries, since part of the blood carried by th bronchial arteries is returned by the pulmonary veins. The superfici and deep bronchial veins unite at the root of the lung, opening on th right side into the large azygos, and on the left usually into the le upper azygos vein.

According to Zuckerkandl it is not only at the extremities of the bronchi tubes that the blood brought by the bronchial arteries is returned by the pu monary veins, but in other parts small bronchial veins open into pulmona branches; and even veins which receive branches from the larger bronchi from the bronchial glands and from the posterior surface of the pericardiu empty their contents partly into the great trunks of the pulmonary veins.

Lymphatics.—Part of the lymphatics of the lung take origin fro lymphatic capillaries in the interalveolar septa, and those near the su face of the lung come into connection with the subpleural lymphat plexus, previously mentioned (p. 503). They join to form vessels whi

many the branches of the pulmonary artery and vein, running on of those vessels in twos or threes, connected by numerous cross and in some cases almost completely surrounding the blood-

lymphatics, which might be distinguished as bronchial, in plexuses in the mucous membrane of the bronchial tubes. they pass through the muscular coat to form another plexus fibrous layer, where they are most numerous on the side the accompanying branch of the pulmonary artery. Here are not unfrequently found to enclose nodules of lymphoid (see p. 214). The branched connective tissue corpuscles and ces with which the lymphatics are in connection at their origin, rocesses upwards to the inner surface of the air tubes and alveoli, the epithelial cells (like the pseudostomata of the serous anes, p. 216). Lymphoid tissue is found, according to Arnold, in parts, viz., under the pulmonary pleura; in the perivascular eribronchial tissue; in the bronchial wall, and around the alveolar ces.

the root of the lung the superficial and deep lymphatics unite a few anastomosing trunks before entering the bronchial lymphatic s.

ves.—The nerves of the lung come from the anterior and pos- pulmonary plexuses which are formed chiefly by branches from the nogastric nerves, joined by others from the sympathetic system. ne nervous cords enter at the root of the lung, and follow the air- According to Remak, whose account has been confirmed and to by the more recent observations of Stirling and others, they e both white fibres, derived in all probability from the vagus, grey filaments proceeding from the sympathetic, and have ganglion- both singly and in groups, upon them in their course. In the vertebrates (frog, newt) the nerves are chiefly distributed to a layer in muscular tissue, which is everywhere found taking part in the osition of the relatively simple pulmonary wall (Stirling), but in mals the final distribution of the nerves requires further exami- n.

ent Literature of the lungs and trachea.—(For older literature see the "Lung" by *F. E. Schultze*, in Stricker's Handbook, 1871); *Rindfleisch*, Muskul. Bronchien, Med. Centralbl., 1872; Verästel. d. Art. pulm., Berl. klin. Wochenschr., ; *Tarchetti*, on the glands of the trachea, in Riv. d. med. &c. di Soresina, 1874; ki, Epith. d. Lungenalv., Med. Centralbl., 1875; *Küttner*, Lungenepith., Virch. , 1876; Kreislauf d. Lunge, Virch. Arch. LXXIII., 1878; *Cohnheim u. Litten*, d. Lungenarterien, Virch. Arch., LXV., 1876; *Cadiat*, Rapp. entre le dével. du n et sa structure, Arch. de physiol., 1877; *Stirling*, Nervous apparatus of the Brit. Med. Journal, 1876; Proc. Roy. Soc., 1880, and Journ. of Anat., 1881; plasia of muscular tissue of lung, Journal of Physiol., 1878; *Aeby*, Bronchial-baum, Centralbl., 1878, and Leipzig, 1880; *Sée*, Calibre de la trach. et des bronches, d. sc. med. XII., 1878; *Frankenhäuser*, Tracheo-bronchial-schleimhaut, Diss., t., 1879; *Veraguth*, Lungenepith., Virch. Arch., LXXXII., 1880; *Kölliker*, Bau nchl. Lunge, Wurzb. Verhandl., 1881; *Kandarazi*, on the nerves of the respir. in Arch. f. Anat., 1881; *Zuckerkandl*, in Wiener Sitzungsb., 1881.

the lymphatics of the lungs. — *Sikorski*, in Med. Centralbl., 1870; *Klein*, ny of Lymphatic System, Part II., 1875; *Ins*, in Arch. f. exp. Pathol., V. 1876, Virch. Arch., LXXIII., 1878; *Nothnagel* in Virch. Arch., LXXI., 1877; ber in Gaz. méd., 1877; *Ruppert* in Virch. Arch., LXXII., 1878; *Schottelius* in Arch. LXXIII., 1878; *v. Wittich*, in Mitth. a. d. Konigsb. physiol. Laborat., 1878; pel in Virch. Arch., *LXXV., 1879*; *J. Arnold*, in Virch. Arch., LXXX., 1880.

THE LARYNX, OR ORGAN OF VOICE

The **larynx** is placed at the upper and fore part of the it forms a considerable prominence in the middle line. It the large vessels of the neck, and below the tongue and hyoi covered in front by the cervical fascia along the middle line side by the sterno-hyoid, sterno-thyroid, and thyro-hyoid m upper end of the thyroid body, and by a small part of the strictor of the pharynx. Behind it, is the pharyngeal muco and above, it opens into the cavity of the pharynx.

The larynx consists of a framework of cartilages, articul and connected by elastic membranes or ligaments, two of ing into the interior of the cavity are named the *true voca* more immediately concerned in the production of the voice special muscles, which move the cartilages one upon anothe its form and the tension of its ligaments, and it is lined membrane, continuous above with the mucous membrane o and below with that of the trachea.

CARTILAGES OF THE LARYNX.

The cartilages of the larynx (fig. 450, 451) consist o and symmetrical prices, named respectively the *thyroid car cricoid cartilage* (fig. 450, 8, fig. 451, 2), and the *cartilage o* (fig. 451, 7), and of three pairs, namely, the two *arytæ* (fig. 451, 3), the *cornicula laryngis*, and the *cuneiform* o all there are nine distinct pieces, but the cornicula a cartilages are very small. Only the thyroid and cric are visible on the front and sides of the larynx; the cricoid cartilage surmounted by the arytenoid cartilag again by the cornicula are seen at the back, whilst th situated in front of, and the cuneiform cartilages on eac upper opening.

The **thyroid** cartilage, the largest, consists of two flat which are continuous in front, forming a narrow angle with like the letter V, most prominent at the upper part. This jection is subcutaneous, and is much more marked in the the female, being named in the former the *pomum Ada* symmetrical halves, named the *alæ*, are somewhat quadrila Of each half the anterior border is the shortest, the pomum surmounted by a deep notch (see fig. 450). The free poste thickened and vertical, and is prolonged upwards and do two processes or *cornua*; it gives attachment to the stylo-pl palato-pharyngeus muscles. The upper and lower bord a well-marked sinuosity close to the cornu: otherwise convex, and the lower nearly straight. The flattened exte each ala is marked by an indistinct oblique line or rid which, commencing at a tubercle, situated at the back upper border, passes downwards and forwards to a tuberc to mark off the anterior three-fourths of the surface from This line gives attachment below to the sterno-thyroid, the thyro-hyoid muscle, whilst the small smooth surface b origin to part of the inferior constrictor of the pharyn

by means of areolar tissue, to the thyroid body. On their rfaces, the alæ are smooth and slightly concave. Of the four of which bend inwards, the two *superior* or *great* cornua pass upwards with sometimes a slight backward curve, and ach by a blunt extremity, which is connected, by means of the o-hyoid ligament, to the tip of the corresponding great cornu

Fig. 450.

ONT VIEW OF THE LARYNGEAL AND LIGAMENTS (Sappey).

ie ; 2, its large cornua ; 3, rnua ; 4, thyroid carti- rro-hyoid membrane ; 6, hyoid ligament, containing *triticea*, 7 ; 8, cricoid crico-thyroid membrane ; co-thyroid ligaments.

d bone (fig. 450, 2). *r* or *smaller* cornua, somewhat thicker but directed slightly for- on the inner aspect of sent a smooth surface, tion with a prominence of the cricoid carti-

icoid cartilage (fig. ch is shaped like a sig- thicker and stronger hyroid. It is deep 451, 2), where it is nto a squarish plate or easuring in the male about an inch from above down- t in front it forms a narrow ring or arch, with a vertical nt of only one-fourth or one-fifth of an inch. Corre- vith this, the *superior border*, which is markedly elevated scends with a deep concavity in front below the thyroid while the *inferior border*, is horizontal, and connected by to the first ring of the trachea. The posterior elevated e upper border is slightly depressed in the middle line ; e sides of this depression are the elongated oval facets ation with the arytenoid cartilages. These facets are nvex and they look outwards as well as upwards. The *rface* of the cartilage is convex and smooth in front and s, where it affords attachment to the crico-thyroid muscles, l these to the inferior constrictors of the pharynx : in line posteriorly is a slight vertical ridge to which some gitudinal fibres of the œsophagus are attached. On each ridge is a broad depression occupied by the posterior crico- uscle, outside which is a small concave rounded and slightly ce for articulation with the inferior cornu of the thyroid car- 458). The *internal surface* is covered throughout by the nbrane *of the larynx*. *At its* lower border the cricoid is cir-

cular, but higher up the cartilage is somewhat compressed that the passage through it is here elliptical.

The **arytenoid** cartilages (fig. 451, 3) are two in numb metrical in form and position. They may be compared irregular three-sided pyramids, and they rest by their bases on and highest part of the cricoid cartilage, while their som apices approach one another. Each is about half an inch quarter of an inch wide. Of the three faces the *posterior* is gular, and concave from above downwards, lodging part of

Fig. 451.

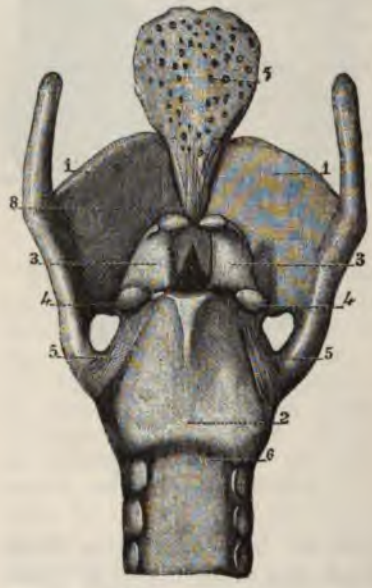


FIG. 451.—BACK VIEW GEAL CARTILAGES (SAPPEY).

1, thyroid cartilage tilage ; 3, arytenoid ca muscular processes ; better marked than the lower cornu of t the back of the crico upper ring of the glottis ; 8, ligament the angle of the thyroi cornicula are seen surm tenoid cartilages.

muscle. The *ante nal*, convex in its line, and somewhat attachment to the noid muscle, and, tubercle, to the superior or false voc *internal* surface, whi rowest of the three, convex, is nearly par of the opposite car covered by the lary membrane. The anterior and posterior borders, which limi face, are nearly vertical, whilst the external border, which anterior from the posterior surface, is oblique.

The *base* of each arytenoid cartilage is slightly holl towards its outer part a smooth surface for articulation wit cartilage. Two of its angles are remarkably prominen *external*, short, and rounded, which projects backwards a and into which the posterior and the lateral crico-arytenoi inserted (*muscular process*) ; the other *anterior*, which is and forms a horizontal projection forwards, to which the true vocal cord is attached (*vocal process*).

The *apex* curves backwards and a little inwards, and te blunt point, which is surmounted by the corniculum laryng

A small cartilaginous nodule (sesamoid cartilage) is sometime side of the arytenoid near the tip, embedded in the perichondrium

The **cornicula laryngis**, or **cartilages of Santorini**, yellowish cartilaginous nodules of a somewhat conical sha

ted with the summits of the arytenoid cartilages (fig. 451), and it were to prolong them backwards and inwards. They some- rm part of the arytenoid cartilages.

uneiform cartilages, or **cartilages of Wrisberg,** are two all, soft, yellowish, cartilaginous bodies, placed, one on each side, ld of the mucous membrane which extends from the summit of tenoid cartilage to the epiglottis. They have a conical form, with e directed upwards. They occasion small elevations of the mu- mbrane, a little in advance of the cornicula, with which, however, e not directly connected.

cartilages are very frequently absent, especially in the white races of d, but according to Gibb are always present in the negro.

epiglottis (fig. 451, 7) is a median lamella of yellow cartilage, somewhat like an obovate leaf, and covered by mucous mem-

It is placed in front of the superior opening of the larynx, ing, in the ordinary condition, upwards immediately behind e of the tongue ; but during the act of swallowing it is carried ards and backwards over the entrance into the larynx, which it and protects.

cartilage of the epiglottis is broad and rounded at its upper free , but inferiorly it becomes pointed, and is prolonged by means of , narrow, elastic band (the *thyro-epiglottic ligament*) to the deep r depression between the alæ of the thyroid cartilage, to which it ched behind and below the median notch. Its *lateral* borders, are convex and turned backwards, are only partly free, the lower eing enveloped in the aryteno-epiglottic folds of mucous mem-

The *anterior* or *lingual* surface is free only in its upper part, it is covered by mucous membrane. Lower down, the membrane cted from it forwards to the base of the tongue, forming three e frænula, the middle and lateral glosso-epiglottic folds. This is also connected below with the posterior surface of the hyoid y a median elastic structure named the *hyo-epiglottic ligament.* terior or *laryngeal* surface, which is free in the whole of its extent, avo-convex from above downwards, but concave from side to side : nvexity projecting backwards into the larynx is named the le or cushion. The epiglottis is closely covered by mucous mem- on removing which, the yellow cartilaginous lamella is seen to be d by numerous little pits and perforations, in which are lodged glands which open on the surface of the mucous membrane.

to the age of puberty the larynx is similar in the male and female, ief characteristics at that period being the small size and com- ve slightness of the organ, and the smooth rounded form of the d cartilage in front. In the female these conditions are permanent, ing that a slight increase in size takes place. In the male, on the ry, at the time of puberty, remarkable changes rapidly occur, and nx becomes more prominent and more perceptible at the upper f the neck. Its cartilages become larger, thicker, and stronger, he alæ of the thyroid cartilage project forwards in front so as to t their union with one another, the prominent ridge of the *pomum* i. At the same time, the median notch on its upper border is erably deepened. In consequence of these changes in the thyroid ge, the distance between *its angle* in front and the arytenoid

cartilages behind becomes greater, and the vocal cords ar lengthened. Hence the dimensions of the glottis, which, s puberty, undergo an increase of about one-third only in th nearly doubled in the male, and the adult male larynx becon one-third larger than that of the female.

Towards the middle of life the cartilages of the laryn tendency to ossification; this commences first in the thyr then appears in the cricoid, and much later in the aryten In the thyroid cartilage the ossification usually begins at th posterior borders; it then gradually extends along the v border, and subsequently spreads upwards through the ca cricoid cartilage first becomes ossified at its upper border n near the two posterior articular eminences, and the ossific the lateral parts of the cartilage before encroaching either c or posterior parts. The arytenoid cartilages become ossifi upwards.

Structure of the cartilages of the larynx.—The cornicula laryngis and the cuneiform cartilages, are comp or yellow fibro-cartilage (p. 82), and have little tendency t apices of the arytenoid cartilages are also formed of elastic f but the greater part of these, as well as the cricoid and thy are composed of hyaline cartilage, resembling generally tha cartilages (p. 81), like which, they are very prone to ossifi advances.

LIGAMENTS AND JOINTS OF THE LARYNX.

The larynx is connected with the hyoid bone by a bro and at the sides of this by two round lateral ligaments. The **membrane** or **middle thyro-hyoid ligament** (fig. 450, fibrous, and somewhat elastic membrane, which passes up fr length of the superior border of the thyroid cartilage to th where it is attached to the posterior and upper margin of inclined inferior surface. Owing to this arrangement, the top when drawn upwards, is permitted to slip within the cir the hyoid bone, between which and the upper part of the t lage there is occasionally found a small synovial bursa. hyoid membrane is thick where subcutaneous towards the out at the sides becomes thin and loose, and is covered hyoid muscles. Behind is the epiglottis with the muco of the base of the tongue, separated, however, by adipo mucous glands. This ligament is perforated by the super artery and nerve of each side. The **lateral thyro-hyoid** (fig. 450, 6), placed at the posterior limits of the thyro brane, are two rounded yellowish cords, which pass up from cornua of the thyroid cartilage, to the extremities of the of the hyoid bone. They are distinctly elastic, and there enclosed in each a small oblong cartilaginous nodule, whi named *cartilago triticea*: sometimes this nodule is bony.

The thyroid and cricoid cartilages are connected togethe branous ligament and synovial articulations. The **crico-th brane** (fig. 450, 9) is divisible into a mesial and two lat The mesial portion, broad below and narrow above, is a stro yellowish ligament, consisting chiefly of elastic tissue, an

rotating movement on a nearly vertical axis, the vocal pro
inclined inwards or outwards (as well as somewhat do
upwards). A combined rotating and gliding movement ma
The ordinary position of the arytenoid, when the larynx is
the outer part of the articular surface on the cricoid. The
crico-arytenoid ligament, arising from the cricoid, and
the inner and back part of the base of the arytenoid cartila

The summits of the arytenoid cartilages and the cornicul
sometimes united by a synovial joint, but most frequently
tissue forming a sort of synchondrosis.

INTERIOR OF THE LARYNX.

The cavity of the larynx is divided into an upper and
partment by the comparatively narrow aperture of the gl
glottidis, the margins of which, in their two anterior thirds
the lower or *true vocal cords*; and the whole laryngeal cav

Fig. 452.

Fig. 452.—ANTERIOR HA
VERSE VERTICAL SECTIO
LARYNX NEAR ITS MIDDLE
1, upper division of the
2, central portion; 3, low
tinued into 4, trachea; *e*,
the epiglottis; *e'*, its cu
cornua of the hyoid bone
membrane; *t*, thyroid car
cartilage; *r*, first ring of
thyro-arytenoid muscle;
arytenoid ligament in the
true vocal cord at the rima
ventricle; above this, the
cords; *s'*, the sacculus or
the right side by carrying
ther forward.

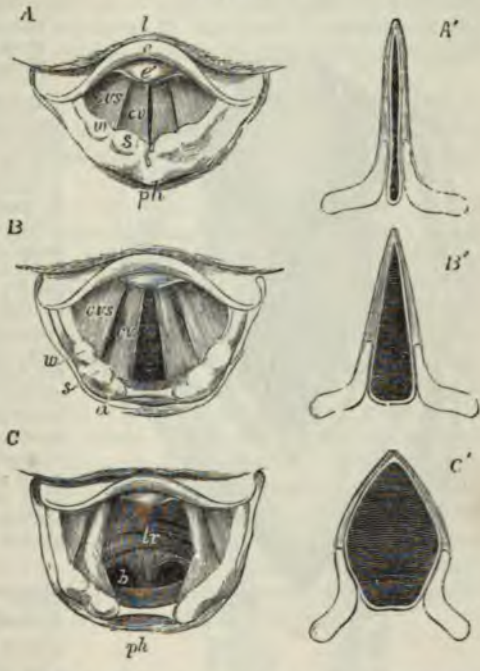
transverse vertical sect
thus presents the ap
an hour-glass. The
partment communica
pharynx by the *supe*
of the larynx, and co
diately above the rima
ventricles (*s*), with thei
saccules, and the up
vocal cords. The low
ment passes inferiorly
of the windpipe without any marked constriction or limita
them. The whole of the interior of the larynx is lined
membrane.

The **superior aperture** of the larynx is triangular, wide
narrow behind, the lateral margins sloping obliquely dow
backwards. It is bounded in front by the epiglottis (fig. 4
fig. 454, *a*), behind by the summits of the arytenoid cartila
B, *a*) and cornicula (*s*) with the angular border of mucou
crossing the median space between them, and on the sides
of mucous membrane, the *arytæno-epiglottic folds*, which,

ntous and muscular fibres and the cuneiform cartilages, pass rom the tips of the arytenoid cartilages and cornicula to the gins of the epiglottis (fig. 454, 8, 9, 10).

ng the form of the laryngeal cavity, and its apertures, it is well to nainted with the appearances which they present on examination by means of the laryngoscope, and with the relations of these to the

Fig. 453.



THREE LARYNGOSCOPIC VIEWS OF THE APERTURE OF LARYNX AND SURROUNDING PARTS IN DIFFERENT STATES OF THE RESPIRING LIFE (from

ttis during the a high note in in easy or quiet air. C, in the st possible dila- inhaling a very The diagrams A', have been added figures to show sections of the position of the ts and arytenoid the three several nted in the other ll the figures, so l, the letters in- arts as follows, se of the tongue; free part of the ', the tubercle the epiglottis; he anterior wall ynx behind the e margin of the ttidean fold *w*, f the membrane cuneiform cartilage; *s*, that of the corniculum; *a*, the tip of the arytenoid *r*, the true vocal cords or lips of the rima glottidis; *c v s*, the superior or rds; between them the ventricle of the larynx; in C, *t r* is placed on the of the receding trachea, and *b* indicates the commencement of the two d the bifurcation, which may be brought into view in this state of extreme

tructure. On thus examining the superior aperture, there are seen e two rounded elevations (fig. 453, *s*, *w*), corresponding respectively cula and the cuneiform cartilages; while in the middle line in front tumescence of the mucous membrane on the lower part of the nabling that structure to close the aperture more accurately when sed, and named the *tubercle* or *cushion of the epiglottis* (*e*). The abrane between the arytenoid cartilages is stretched when they are , C), and folded double when they are approximated (A).

g down through the superior opening of the larynx, the *glottis* or *is* (fig. 454, *c*) is seen at some distance below, in the form of a long re running from before backwards. It is situated on a level with art of the arytenoid cartilages, and is bounded by the *true* vocal

cords. Above the glottis, another pair of projecting folds is seen, t
or *false vocal cords*, which are much less projecting than the inferi
the superior and inferior vocal cords, the *sinus* or *ventricle* is seen
gated depression (fig. 452, *s*, and fig. 454, *b'*).

The **superior vocal cords**, also called the *false* vocal co
they are not immediately concerned in the production of th
prominent rounded folds of mucous membrane enclosing ve

Fig. 454.

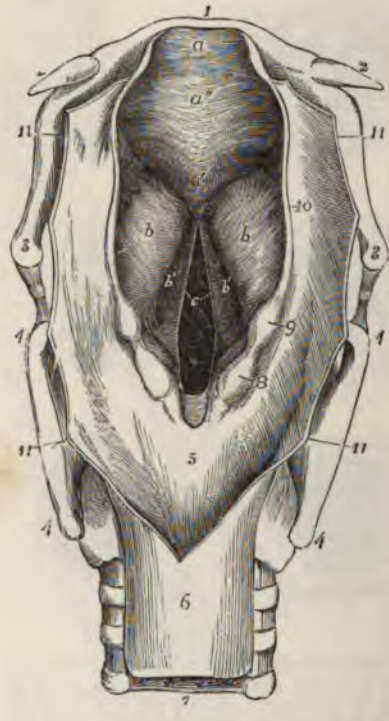


Fig. 454.—PERSPECTIVE
PHARYNGEAL OPENING
RYNX FROM ABOVE AND
Thomson).

The superior aperture
dilated; the glottis is in
dilated condition; the wa
rynx is opened from behi
to the sides. 1, body of t
2, small cornua; 3, gre
cornua of the thyroid carti
brane of the pharynx cov
terior surface of the cricoi
gullet; 7, trachea; 8, pr
by the cartilage of Sant
same belonging to the ca
berg; 10, aryteno-epiglotti
cut margin of the wall of
a, free part of the epig
lower pointed part; *a''*, t
eminence on each side ov
or pouch of the larynx; *b'*,
c, the glottis intermembra
lines on each side point
cords; *d*, intercartilaginou
glottis.

glands which form
arched projections, i
above the correspondi
(fig. 454, *b*). The la
on looking down into
geal cavity, the sup
cords (*cvs*, fig. 453) be
apart than the inferio

The **inferior or true vocal cords**, the structures by the
which the sounds of the voice are produced, bound the t
thirds of the aperture of the glottis, corresponding with the t
noid ligaments (fig. 454, *c*). The mucous membrane coveri
so thin and closely adherent as to show the yellowish colour
ments through it. Their free edges, which are sharp and st
directed upwards, form the lower boundaries of the ventric
the parts thrown into vibration during the production of
Their inner surfaces are flattened, and look towards each othe

The **rima glottidis**, an elongated aperture, situated,
between the inferior or true vocal cords, and, posteriorly, t
bases of the arytenoid cartilages, forms a long narrow slit, sli
in the centre when nearly closed, as in the production of the v

y open, as in easy respiration, its shape is that of a long triangle, ed extremity being directed forwards, and the base being tween the arytenoid cartilages (fig. 453, B'); in its fully dilated it is lozenge-shaped (the posterior sides being formed by the s of the bases of the arytenoid cartilages), while the posterior uncated (C'). The rima glottidis is the narrowest part of the f the larynx; in the adult male it measures about 23 mm., an inch, in an antero-posterior direction, and 6 or 8 mm. its widest part, which may be dilated to nearly 12 mm. In , and in males before the age of puberty, its dimensions are less, posterior diameter being about 17 mm., and its transverse dia- at 4 mm. The vocal cords are about 15 mm. long in the adult 11 mm. in the female.

ntricles or **sinuses** of the larynx (fig. 452, *s*, and fig. 454, *b'*) er at their orifice than in their interior. The outer surface of ered by the upper fibres of the corresponding thyro-arytenoid

all recesses named the *laryngeal pouches* (fig. 452, *s'*), lead anterior part of the ventricles upwards, for the space of half between the superior vocal cords inside and the thyroid utside, reaching as high as the upper border of that cartilage of the epiglottis. The pouch, which is of variable size, is shape, and curved slightly backwards. Its opening into the is narrow, and is generally marked by two folds of the lining embrane. Numerous small mucous glands, sixty or seventy in pen into its interior, and it is surrounded by a quantity of fat. to the fat, this little pouch receives a fibrous investment, ontinuous below with the superior vocal cord. Over its laryn- and upper end is a thin layer of muscular fibres (compressor yngis, arytæno-epiglottideus inferior, Hilton) connected above found in the aryteno-epiglottidean folds. The upper fibres yro-arytenoid muscles pass over the outer side of the pouch, g attached to its lower part. The laryngeal pouch is supplied y with nerves, derived from the superior laryngeal.

MUSCLES OF THE LARYNX.

certain extrinsic muscles elsewhere described—viz., the sterno- o-hyoid, sterno-thyroid, and thyro-hyoid muscles, together muscles of the suprahyoid region, and the middle and nstrictors of the pharynx, all of which act more or less upon larynx—there are other muscles which move the different upon one another, and modify the size of the apertures and the nsion of the vocal cords. These intrinsic muscles are the *crico-* he *posterior crico-arytenoid*, the *lateral crico-arytenoid*, the *enoid*, the *arytenoid*, and the *aryteno-epiglottidean*, together in other slender muscular fasciculi. All these muscles, except oid which crosses the middle line, are in pairs.

co-thyroid muscle (fig. 455, 10), is a short thick triangular en on the front of the larynx. Its attachment below, to the tilage, extends from the median line a considerable way back- l its fibres passing upwards and outwards, diverging slightly, bove to the inferior border of the thyroid cartilage, and to the

anterior border of its lower cornu. The latter portion of the mus
fibres of which are nearly horizontal, is usually distinct from th
Some of the superficial fibres are almost always continuous wi
inferior constrictor of the pharynx. The muscles of the two sid

Fig. 455.

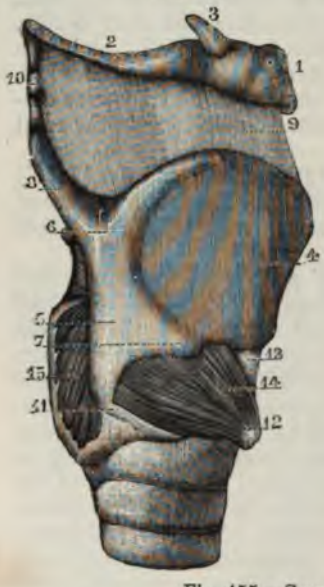


Fig. 455.—Side view of the larynx (Sappey).

1, hyoid bone; 2, 3, its cornua; 4, right ala of thyroid cartilage; 5, posterior
the same separated by oblique line from anterior part; 6, 7, superior and inferio
cles at ends of oblique line; 8, upper cornu of thyroid; 9, thyro-hyoid ligame
cartilago triticea; 11, lower cornu of thyroid, articulating with the cricoid; 12,
part of cricoid; 13, crico-thyroid membrane; 14, crico-thyroid muscle; 15,
crico-arytenoid muscle partly hidden by thyroid cartilage.

Fig. 456.

Fig. 456.—Posterior muscles of the larynx (Sappey).

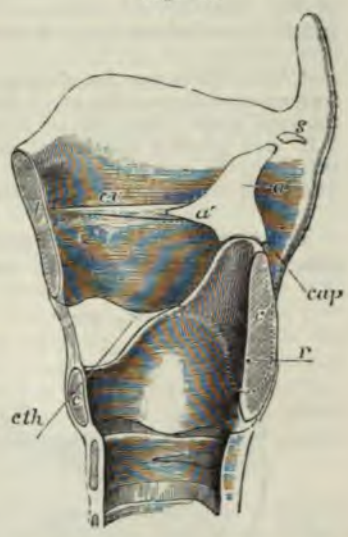
1, posterior crico-arytenoid; 2, arytenoid muscle; 3, 4, oblique fibres passing
the edge of the arytenoid cartilage to join the thyro-arytenoid, and to form the
epiglottidean, 5.

somewhat separate from one another in the middle line in front, l
an interval which is triangular with the base upwards. The crico-t
membrane is here exposed.

Action. The anterior part of the muscle contracting will approxima
cricoid and thyroid cartilages in front. In this action the thyroid is fi
the extrinsic muscles, and the anterior part of the cricoid rotating on th
which unites the articulations between the cricoid and the lower cornua
thyroid is drawn upwards, and the part behind the crico-thyroid joi
depressed, and with it the arytenoid cartilages, so that the vocal cords ar
put on the stretch. This stretching of the vocal cords is still further assis
the action of the oblique fibres, which acting from the cornu of the fixed th
draw the cricoid cartilage backwards. The muscle is generally described as
from the cricoid, but as Jelenffy has shown, it is the thyroid that is fi

ation, the cricoid being moveable, and indeed receiving no extrinsic
capable of fixing it effectually. It is found also that with electric exci-
of this muscle the anterior part of the cricoid is raised towards the thyroid.
is of these muscles is accompanied by inability to produce high tones of
ce.

Fig. 457.



7.—Outline of the right half the cartilages of the larynx as from the inside, with the thyro-noid ligament, to illustrate the n of the crico-thyroid muscle a Thomson).

roid cartilage; *c*, cricoid cartilage; arytenoid cartilage; *a'*, its vocal ; *s*, corniculum; *c v*, the thyro-ary-ligament; the position of the lower f the thyroid cartilage on the out-the cricoid is indicated by a dotted , and *r* indicates the point or axis of n of the cricoid cartilage on the cornu thyroid; *c t h*, a line in the prin-direction of action of the crico-thyroid ; *c a p*, the same of the posterior rytenoid muscle.

e **posterior crico-arytenoid cle** (fig. 456, 1), situated be-, arises from the broad de-ion on the corresponding half e posterior surface of the cricoid age, and its fibres, converging rds and outwards, are inserted into the outer angle of the base of rytenoid cartilage, behind the attachment of the lateral crico-noid muscle. The upper fibres are short and almost horizontal; middle are the longest and run obliquely; whilst the lower or nal fibres are nearly vertical.

ion. The posterior crico-arytenoid muscles draw the outer angles of the oid cartilages backwards and inwards, and thus rotate the anterior or vocal ses outwards, and widen the rima glottidis. They may also draw the ary-cartilages apart. They come into action during deep inspiration. If sed the lips of the glottis approach the middle line, and come in contact each inspiration, so that severe dyspnoea may be produced. Expiratory , however, are not impeded, and vocalization is unaffected.

riety.—In connection with the posterior crico-arytenoid muscle, may be oned an occasional small slip in contact with its lower border, viz., the **o-cricoid** muscle of Merkel. It is a short and slender bundle, arising from icoid cartilage near its lower border, a little behind the inferior cornu of yroid cartilage, and passing obliquely outwards and upwards to be inserted hat process. It usually exists on only one side. Turner found it in seven thirty-two bodies. It is not known to be of any physiological significance. el. Anat. und Phys. des menschl. Stimm-und Sprach-organs, Leipzig, 1857; r in Month. Med. Journal, Feb. 1860.)

e **lateral crico-arytenoid muscle** (fig. 458, *f*), smaller than the rior, is in a great measure hidden by the ala of the thyroid cartilage. along the sloping upper border of the cricoid cartilage, from which es, its origin *extending as far back as the* articular surface for the

arytenoid. Its fibres pass backwards and upwards, the anterior o ones being necessarily the longest, and are attached to the m process of the arytenoid cartilage and to the adjacent part of its surface.

This muscle is covered internally by the lateral part of th thyroid membrane, and externally at its anterior part by the up of the crico-thyroid muscle. The upper part is in close cont indeed is sometimes blended with the thyro-arytenoid.

Action. These muscles, drawing the muscular processes of the forwards and downwards, rotate the vocal processes inwards, and app the vocal cords. They thus act antagonistically to the posterior crico-ar

If both posterior and lateral crico-arytenoids be thrown into actio taneously, the arytenoids will not undergo rotation, but will be draw wards and outwards, and the glottis will thus be widened.

The **thyro-arytenoid muscle** consists of two portions, one situated immediately within the ala of the thyroid cartilage,

Fig. 458.

Fig. 458.—SIDE VIEW LARYNX AFTER REMOV RIGHT ALA OF THE CARTILAGE (S. G. Shat

h, body of hyoid b *e*, epiglottis; *th*, cut right ala of thyroid *cr*, front of cricoid cart articular faces for the corner of the thyroid is teriorly; *th.ar*, *th.ar*, fib thyro-arytenoid (outer passing from the thyroi to the arytenoid behind others arising from the roid membrane; another able mass of fibres is see from the same parts, and at first obliquely and af nearly vertically upward thyro-epiglottidean muscle *th.ar.m*, small thyro-ar *th.ar.m'*, a small slip of muscle passing into the fo cord; *cr.ar.lat*, lateral cri noid; *cr.ar.p*, posteri arytenoid; *r.ar.ep*, right epiglottidean muscle origin; *l.ar.ep*, left epiglottidean near its i *l.ar.ep'*, portion of the sam into the corniculum; *f* saccule covered by mucou

internal lying in close contact with the vocal cord. Sometimes th described as distinct muscles under the names external and interna arytenoid (Henle), but the separation between them has general effected by artificial means. The inner portion of the muscle is tri in section corresponding with the vocal fold which it occupies; th is laterally compressed and extends both above and below th portion. Each contains both antero-posterior and oblique fibres.

er portion.—The antero-posterior fibres of the internal portion n the lower half of the angle formed by the alæ of the thyroid ge, a few even from a nodule of firmer elastic tissue (sometimes bed as fibro-cartilage) in the anterior part of the vocal cord itself; assing backwards in a slight curve with the concavity inwards, are ed behind to the vocal process along its whole length and to the nt part of the outer surface of the arytenoid cartilage. They ined internally by short fibres which are attached in front to cal cord, and behind to the vocal process of the arytenoid (*portio calis* of Ludwig); and externally they are contiguous with the antero- ior fibres of the external portion. The oblique fibres of the internal n pass from the sloping portion of the crico-thyroid membrane below cal cord proper (in its anterior third), upwards, outwards, and what backwards, passing between the antero-posterior fibres, and he ventricle of Morgagni to end in the tissue of the false vocal fold. ter portion (fig. 458).—The fibres of the external portion arise in from the thyroid cartilage close to the origin of the internal por- and from the crico-thyroid membrane; from here they in part ackwards to be inserted into the lateral border and muscular pro- of the arytenoid cartilage, in part obliquely upwards towards the no-epiglottidean fold; some which are more vertical in direction ng in a thin layer around the ventricle of Morgagni and the sac- to end in the false vocal fold. The portion of this muscle which ds towards the epiglottis is often described as a separate muscle r the name of **thyro-epiglottidean** (fig. 458, *th.ep*).

tion.—The bundles of the thyro-arytenoid muscle, differing as they do in tion and in points of attachment, must differ also in their action, if sepa- y called into play. The antero-posterior fibres will tend to draw forwards rytenoid, and with it the posterior part of the cricoid cartilage, rotating the r upwards, and antagonising the action of the crico-thyroid, the effect being lax the vocal cords. But if the latter be kept stretched and approximated ie action of other muscles, those fibres of the inner portion which are in contact with the vocal cord may serve to modify its elasticity and consist- ; while the fibres which constitute the portio ary-vocalis may serve, as wig has pointed out, to tighten the parts of the cord in front of their chment, and to slacken the parts behind. The vertical fibres of the muscle h extend from the sloping part of the crico-thyroid membrane across the of the vocal fold, and over the ventricle into the false vocal cord, must, n they contract, render the free edge more prominent. Finally, the fibres h are inserted into the muscular process of the arytenoid will tend to rotate ocal processes inwards, and those which pass up into the aryteno-epiglottidean may assist in depressing the epiglottis.

the thyro-arytenoid muscles are paralysed, the lips of the glottis are no er parallel, but are curved with the concavity towards one another, and a h stronger blast of air is required for the production of the voice.

ntorini described three thyro-arytenoid muscles, an *inferior*, a *middle*, and a *rior*. The latter is not always present. The inferior thyro-arytenoid muscle antorini comprises most of the antero-posterior bundles; the middle thyro- noid, the oblique bundles of the external portion. The fibres of the superior culus, when present, arise nearest to the notch of the thyroid cartilage, and ttached to the upper base of the arytenoid cartilage (fig. 458, *th.ar.m.*) is named by Sœmmerring the *small* thyro-arytenoid whilst the two other ons of the muscle constitute the *great* thyro-arytenoid of that author.

hen the mucous membrane is removed from the back of the arytenoid lages, a thick band of *transverse* fibres constituting the arytenoid

muscle is laid bare (fig. 456, 2), and on the surface of this are slender decussating oblique bundles (3, 4), formerly described as of the arytenoid muscle (arytænoideus obliquus), but now more considered as parts of the aryteno-epiglottidean muscles, with w are closely associated both in the disposition of their fibres an action. The **arytenoid muscle** (fig. 456, 2) passes straig between the arytenoid cartilages, and its fibres are attached to extent of the concave surface on the back of each. The **epiglottidean** muscles (fig. 456, 5; fig. 458, *l.ar.ep*) aris the inferior and outer angles of the arytenoid cartilages, one with the other, and their fibres are partly attached to and outer part of the opposite cartilage, partly pass forwar aryteno-epiglottic fold, and partly join the fibres of the thyro- muscle.

Action.—The *arytenoid* muscle draws the arytenoid cartilages tog from the structure of the crico-arytenoid joints, this approximation plete is necessarily accompanied with depression. If the muscle is the intercartilaginous part of the glottis remains patent, although

Fig. 459.

Fig. 459.—VIEW OF THE INTE RIGHT HALF OF THE LARYN

1, ventricle; 2, superior, an vocal cord; 4, arytenoid cartil by mucous membrane; 5, aryte cut across; 6, slope of crico-th brane leading up to inferior 6′, lower border of cricoid carti sections of cricoid; 9, its up 10, section of thyroid; 11, up larynx; 12, 13, glandular pro ary-epiglottidean fold; 14, 16, 15, fat between it and the membrane; 17, section of epi section of hyoid bone; 19, 20,

branous lips can still be app The *aryteno-epiglottideus* mu approximate the arytenoid which they include in thei and draw down the epiglotti contract the whole superior of the larynx.

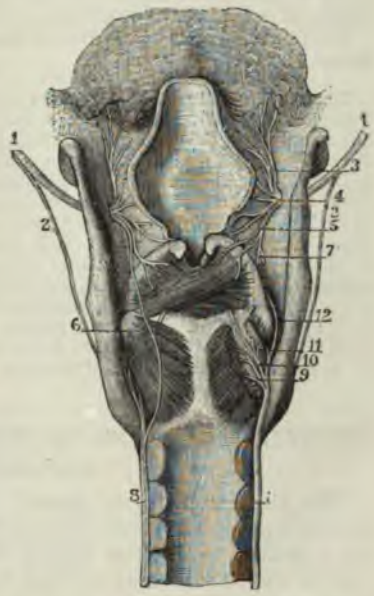
It is remarked by Henle muscles "which lie in the closed by the laminæ of t cartilage, and above the cri be regarded in their totality of sphincter, such as is fo simplest form embracing th of the larynx in reptiles."

THE MUCOUS MEMBRANE AND VESSELS OF THE LARY

The laryngeal **mucous membrane** is thin and of a pale co some situations it adheres intimately to the subjacent parts, on the epiglottis, and still more in passing over the true vo on which it is very thin and most closely adherent. A

r part of the larynx, above the glottis, it is extremely sensitive. d near the aryteno-epiglottic folds, it covers a quantity of loose r tissue, which is liable in disease to infiltration, constituting n of the glottis. Like the mucous membrane in the rest of the ssages, that of the larynx is covered in the greater part of its t with a columnar ciliated epithelium, by the vibratory action of h the mucus is urged upwards. The cilia are found higher up in than on each side and behind, reaching in the former direction as as the widest portion of the epiglottis, and in the other directions to a line or two above the superior vocal cords; above these points epithelium loses its cilia, and assumes a stratified squamous like that of the pharynx and mouth. Upon the true vocal

Fig. 460.



60.—Posterior view of the nerves of the larynx (Sappey).

uperior laryngeal nerve; 2, its branch crico-thyroid muscle; 3, 4, 5, branches mucous membrane of the larynx; 6, nts uniting the left superior and in- laryngeal nerves; 7, the same on the side, cut; 8, 8, inferior laryngeal s; 9, branch to the posterior crico-ary- d muscles; 10, branch to the arytenoid; 2, branches passing to the lateral crico- noid and the thyro-arytenoid muscles.

s also the epithelium is squa- s, although both above and w them it is columnar and ted. Patches of stratified squa- s epithelium are found also ed here and there in the ciliated t above the glottis, especially on under surface of the epiglottis, inner surface of the arytenoid ilages, and at the free border of superior vocal cord. Bodies ch are to all appearance similar the taste-buds presently to be cribed in the mucous membrane of the tongue are found imbedded in s stratified epithelium.

The lining membrane of the larynx is provided with numerous *glands*, ich secrete an abundant mucus; and the orifices of which may be n almost everywhere, excepting upon and near the true vocal cords. ey abound particularly upon the epiglottis, in the substance of which found upwards of fifty small compound glands, some of them per- ating the cartilage. Between the anterior surface of the epiglottis, hyoid bone and the root of the tongue, is a mass of yellowish fat, oneously named the epiglottic gland, in or upon which some small nds may exist. Another collection of glands is placed within the fold mucous membrane in front of each arytenoid cartilage, from which eries may be traced forwards, along the corresponding superior vocal d. The glands of *the laryngeal pouches* have already been noticed.

Vessels and Nerves of the Larynx.—The *arteries* of the larynx a from the superior thyroid, a branch of the external carotid, and from th thyroid, a branch of the subclavian. The *veins* join the superior, mi inferior thyroid veins. The *lymphatics* are numerous, and pass thr cervical glands. Their mode of distribution resembles that in the trac *nerves* are supplied from the superior laryngeal and inferior or laryngeal branches of the pneumogastric nerves, joined by branch sympathetic. The superior laryngeal nerves supply the mucous mem the crico-thyroid muscles, and also in part the arytenoid muscle. Th laryngeal nerves supply, in part, the arytenoid muscle, and all the othe excepting the crico-thyroid.

The superior and inferior laryngeal nerves of each side communicate other in two places, viz., at the back of the larynx, beneath the p mucous membrane, and on the side of the larynx, under the ala of th cartilage. Numerous ganglion-cells are found on the branches, both which enter the muscles, and also underneath the mucous membrane. are also described in the mucous membrane which covers the po laryngeal surface of the epiglottis (Lindemann).

The further details of the distribution of the vessels and nerves will in vol. 1.

Recent literature of the larynx.—*Luschka*, Der Kehlkopf des Tübingen, 1871 ; *Jelenffy* in Pflüger's Archiv. VII., 1871, and Wiener med. W 1872 ; *Schech* in Zeitschr. f. Biol. IX., 1873 ; *Coyne* (mucous membrane) i Micro. Journal, 1874 ; *Heitler*, Aden. Subst. in d. Schleimhaut, Wiener me 1874 ; *Rühlmann* (Muskeln) Wien. Sitzungsb., LXIX., 1874 ; *Disse*, Beitra Arch. f. mikr. Anat., XI., 1875 ; *Ziemssen*, Article "Diseases of respiratory a in his Handbook, 1876 ; *W. Gruber*, in Virch. Arch., LXVI., LXVII., 1876 ; S Memoires, XXIII., 1876 ; and Arch. f. Anat., 1875 and 1876 ; *Rüdinger*, Bei in Monatschr. f. Ohrenheilk., 1876 ; *Schofield*, in Journ. of Anat., 1876 (tas epiglottis) ; *Weinberg*, Gestalt d. Kehlkopf in versch. Lebensaltern, Arch. f. rurg., 21, 1877 ; *Davis*, Die becherförm. Organe d. Kehlk., Arch. f. mikr. A 1877 ; *Moura*, Dim. d. diverses parties d. lèvres vocales, Bull. de l'acad. 1879 ; *Grützner*, Article "Stimme u. Sprache" in Hermann's Handb. der Phys *S. G. Shattock*, in the Journal of Anatomy, 1882 (thyro-arytenoid muscle).

DUCTLESS GLANDS ON THE LARYNX AND TRA

THE THYROID BODY.

The **thyroid body** or **gland** (fig. 461) is a highly vascula consisting of two *lateral lobes*, united together towards their lo by a transverse portion named the *isthmus*. Viewed as a wh convex on the sides and in front, forming a rounded projection trachea and larynx. It is covered by the sterno-hyoid, sterno and omo-hyoid muscles, and behind them it comes into contact sheath of the great vessels of the neck. Its deep surface is where it rests against the trachea and larynx. It usually exten back as to touch the lower portion of the pharynx, and on the the œsophagus also.

Each lobe extends from the fifth or sixth ring of the trach side of the thyroid cartilage, of which it covers the inferior c part of the ala near the posterior border.

The transverse part, or isthmus (*i*), commonly lies across th third, and fourth rings of the trachea, but is very inconstan shape, and position. From the upper part of the isthmus, or adjacent portion of either lobe, a slender conical process, n *pyramid*, or *middle lobe*, often proceeds upwards to the hyoid which its apex is attached by loose fibrous tissue.

process usually lies somewhat to the left; occasionally it is thicker above below, or is completely detached, or is split into two parts: sometimes it to consist of fibrous tissue only. In many cases muscular fasciculi, most tly derived from the thyro-hyoid muscle, but occasionally independent, from the hyoid bone to the thyroid gland or its pyramidal process. They own as the *levator glandulæ thyroideæ* (fig. 461, *lt*). It sometimes, though happens that the isthmus is altogether wanting, the lateral lobes being connected by areolar or fibrous tissue only: this is the natural condition in nimals.

lateral lobe measures about two inches in length, an inch and a quarter dth, and three-quarters of an inch in thickness at its largest part, which w its middle: the right lobe is usually a little longer and wider than the

isthmus measures nearly half an inch in breadth, and from a quarter to quarters of an inch in depth.

weight of the thyroid body is ordinarily from one to two ounces. It is larger in females than in males, and appears in many of the former to go a periodical increase about the time of menstruation. It varies a good

Fig. 461.

461.—SKETCH SHOWING THE FORM AND POSITION THE THYROID BODY (Allen Thomson). ONE-HALF NATURAL SIZE.

larynx and surrounding parts are viewed from ; on the right side the muscles covering the id body are retained, on the left side they are ved; *h*, hyoid bone; *th*, right thyro-hyoid muscle; mo-hyoid; *sh*, sterno-hyoid; *st*, sterno-thyroid; o-thyroid membrane; *tr*, trachea; *œ*, œsophagus; t lobe of the thyroid body; *t'*, the left lobe; *i*, thmus; *lt*, the fibrous or muscular band termed r thyroideæ, which is more rarely found in the le line or to the right side, and which existed in ase from which the figure was taken.

in size, and occasionally undergoes enormous rgement. Its *colour* is usually of a dusky rnish red, but sometimes of a yellowish hue.

Structure.—The texture of this organ rm, and to the naked eye appears coarsely nular. It is invested by a thin transtent layer of dense areolar tissue, which nects it with the adjacent parts, and perfectly separates its substance into small lobules of irregular form d size.

When the organ is cut into, a yellow glairy fluid escapes from the cut face. Imbedded in its substance are multitudes of closed *vesicles* g. 462), which are held together in groups or imperfect lobules by olar tissue. The size of the vesicles varies from $\frac{1}{500}$th of an inch to t of a millet-seed, so as to be visible to the naked eye. They are erical, polyhedral, or flattened in shape. The wall of each vesicle sists of a simple layer of cubical or columnar epithelium-cells. ording to Baber there is no basement membrane.

The vesicles may contain, besides the characteristic yellow glairy fluid loid), detached epithelium-cells, white blood-corpuscles, parenchyma- which seem to have migrated into the cavities, and also according Baber red blood-*corpuscles in various* stages of disintegration and

decolourization. From this it is inferred that the thyroid bod be concerned in producing retrogressive changes in the blood.

In the interstitial connective tissue of the gland there occur a n of cells similar to the "plasma-cells" of Waldeyer ("parenchyma- Baber). The spaces (areolæ) of this tissue may be filled with th colloid substance as that which occupies the vesicles. The blood- and lymphatics are conducted to the vesicles in the interstitial tis

Fig. 462.

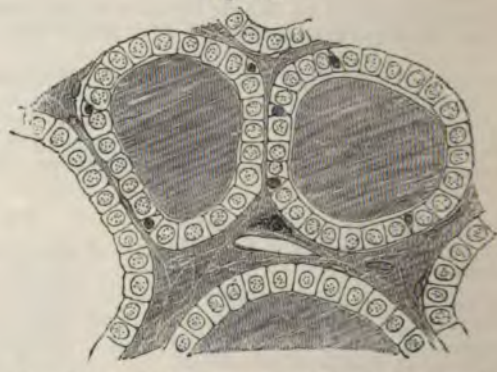


Fig. 462.—Section of the thyroid gland of a child (E. A. S.)

Two complete vesicles and portions of others are represented. The vesicles a with colloid which also occupies the interstitial spaces. In the middle of on spaces a blood-vessel is seen cut obliquely, and close to it is a plasma-cell. Betw cubical epithelium cells, smaller cells like lymph-corpuscles are seen here and the

lymphatic vessels not coming into such intimate relations with th of the vesicles as the blood-capillary network, the vessels of which close contact with the epithelium and may even project betwe epithelium-cells.

Although the vesicles are as a rule quite distinct from each other in the incompletely developed portions may here and there be found in which a mosing cylinders of columnar cells occur.

One of the most frequent pathological changes to which the thyroid subject consists in the accumulation within its vesicles of colloid subs in certain forms of goitre it distends them to an enormous degree.

In the fœtus, and during early infancy, this organ is relatively larger t after-life; its proportion to the weight of the body in the new-born infan that of 1 to 240 or 400, whilst at the end of three weeks it becomes only 1 t and in the adult 1 to 1800 (Krause). In advanced life the thyroid body is to become indurated, and frequently contains earthy deposit; its vesicl attain a very large size.

Vessels and nerves.—The *arteries* of the thyroid body are the superi inferior thyroids of each side, to which is sometimes added a fifth ves *thyroidea ima*. The arteries are remarkable for their large relative size, their frequent and large anastomoses; they terminate in a capillary n upon the outside of the vesicles. The *veins*, which are also large, ultimate plexuses on the surface, from which a superior, middle, and inferior thyr are formed on each side. The superior and middle thyroid veins open i internal jugular; the inferior veins issue from a plexus formed in front trachea, and open into the innominate veins. The *lymphatics* of the body form numerous and large anastomosing trunks, both at the surface

and throughout its substance; they originate, according to the observations y, in the connective tissue which unites the gland-vesicles, with the cavity ich they appear not to be in communication. They contain, besides lymph, substance, similar to that found within the vesicles (Baber).

Nerves are derived from the middle and inferior cervical ganglia of the thetic. They accompany the blood-vessels; and have here and there ion-cells in their course; their mode of ending is unknown.

ent Literature.—*Peremeschko* in Zeitschr. f. wiss. Zool., 1867; *W. Müller* in Zeitschr., 1871; *Verson*, Article in Stricker's Handbook, 1871; *Boéchat*, Thesis, 1873; *Poincaré* in J. de l'anat., 1875; *Baber* in Phil. Trans., 1876 and 1881; Dissert., Strassburg, 1877; (on anatomical peculiarities of the thyroid) *W. Gruber* h. f. Anat., 1876 and in Virch. Arch. LXVI., 1876; (on an accessory thyroid) in Arch. f. Anat., 1879.

THE THYMUS GLAND.

e **thymus gland** or **body** is a temporary organ which reaches its est size at about the end of the second year of life, after which period ses to grow, and is gradually reduced to a mere vestige. Its function t fully understood, although it is probable that it is in some way ected with the elaboration of the blood in infancy. When examined s mature state in an infant under two years of age, it appears as a w elongated glandular-looking body, situated partly in the thorax, partly in the lower region of the neck (fig. 463): below, it lies in uperior mediastinal space, close behind the sternum as far down as ourth rib-cartilage, and in front of the great vessels and pericardium; e, it extends upwards upon the trachea in the neck as high as the r border of the thyroid, being covered by the sterno-hyoid and sterno- id muscles. Its colour is greyish, with a pinkish tinge; its con- nce soft and pulpy, and its surface appears distinctly lobulated. It ists of two *lateral lobes*, which touch each other along the middle line, are of a nearly symmetrical long pyramidal form, though generally ual in size, sometimes the left, and at other times the right lobe being larger of the two. An *intermediate lobe* often exists between the lateral ones, and occasionally the whole body forms a single mass.

xternally the gland is in contact with the pleura, near the internal mary artery, and higher up (in the neck), with the sheath of the tid artery. The dimensions of the thymus vary according to its e of development. At birth it measures rather more than two es in length, an inch and a half in width at its lower part, and about quarter or one third of an inch in thickness. Its weight at that od is about half an ounce.

puberty the thymus is generally reduced to a mere vestige which has entirely its original structure, and consists of brownish tissue occupying part of the rior mediastinum. Occasionally it is still found in good condition at the ntieth year; but generally only traces of it remain at that time, and these arely discoverable beyond the twenty-fifth or thirtieth year.

tructure.—The lateral lobes of the thymus gland are each invested thin capsule of areolar tissue, which sends partitions into the gland een the lobules: on its outer surface the capsule is covered by a of flattened cells. Each lobe consists of numerous polyhedral es, connected by a more delicate intervening areolar tissue. These ary lobules are made up of a number of small nodules or follicles 464, *b*, *b*), one to two millimetres in diameter. Each follicle

is composed of a central part or *medulla*, and an external larger p
cortex. The cortex is in many respects similar in structure to a
nary lymphoid follicle, such as those of the tonsils or of Peyer's p
in the intestine: consisting, like these, of retiform tissue compos
network of branched cells, and of a fine *reticulum* (Watney), the

Fig. 463.

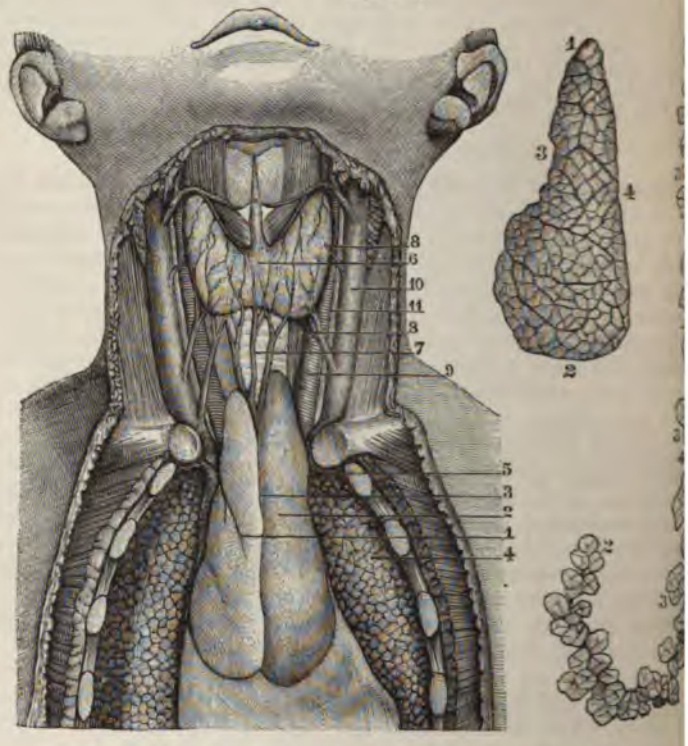


Fig. 463.—The thymus in a child of six months (Sappey).

A. Situation, form and relations of the gland. 1, right lobe; 2, left lobe; 3, furrow; 4, lung, somewhat everted; 5, internal mammary vein; 6, thyroid 7, 8, inferior thyroid veins, mesial and lateral; 9, common carotid artery; 10, jugular vein; 11, pneumogastric nerve. B. Right lobe of the thymus after its envelope; 1, its apex; 2, its base; 3, thin outer border; 4, thick inner C. The gland unravelled, showing the lobules grouped around a central cord; central cord or strand of connective tissue, connecting the lobules.

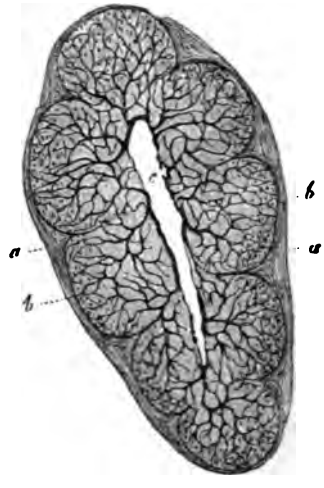
of both being filled with lymphoid cells (thymus corpuscles); at the face of the follicle the retiform tissue is somewhat closer, so as to fo species of capsule for it. In some animals these capsules completely en the follicles, but in others, including man, several follicles may be u towards the centre of the lobule, which is then commonly of softer sistence than the other parts, and apt to break down if not perfectly f so as to give the deceptive appearance of a central cavity (see fig. 4

In the medulla, the retiform tissue is coarser and the lymphoid

"; but it contains here and there peculiar corpuscles, which present
pearance of concentric striation, and are known as the *concentric*
cles of Hassall. They vary in size from that of a blood-corpuscle
ree times that diameter, or more; the larger often contain smaller
in their interior.

ch is composed of an envelope of epithelioid cells enclosing a
al mass, formed of one or more granular cells. The latter are also
l, unenclosed, in the retiform tissue of the follicle, and occasionally
a large size (giant-cells). The concentric corpuscles are often
ed to blood-vessels and to each other by bands of fibrous tissue,
has been inferred by Afanassiew that they are merely portions of
s which have become atrophied, but according to Watney this is not
e; since, at the time when they are most abundant, the formation
od-vessels, and of blood-corpuscles within them, is proceeding most
ly in the glands. Cysts, lined with ciliated epithelium, have been
by Watney in the thymus of the dog.

Fig. 464.



64.—SECTION OF A LOBULE OF AN INJECTED
ANTILE THYMUS GLAND (from Kölliker).
IFIED.

psule of connective tissue surrounding the
; *b*, *b*, follicles; *c*, cleft in the centre of
ule, probably produced by the shrinking
the soft follicular substance.

retrogressive development of the
is accompanied by an increase in the
itial connective tissue, which also
s the follicles. In this tissue plasma-
become accumulated, and are eventually
formed into fat-cells, the normal struc-
of the thymus becoming gradually
ated.

sels and Nerves.—The *arteries* of
ymus are derived from various sources,
m the internal mammary, the inferior
superior thyroid, the subclavian and
id arteries. Their branches penetrate
e follicles, where they form a plexus
h surrounds the cortex and from which
llaries converge towards the medulla. In some animals these vessels loop
towards the cortex, but in others they open into an inner vascular circle
h lies just within the boundary of the medulla. The *veins*, for the most part,
into the left innominate vein.

e *lymphatics* are large. According to the observations of His on the calf,
rger blood-vessels passing to the centre are each accompanied by two or
lymphatic trunks. These arise from an interlobular plexus, which again is
nnection with vessels which surround and enclose the individual follicles
ut penetrating them (as in those of the intestine).

nerves are very minute. Haller thought that they were partly derived
the phrenic nerves, but according to Cooper, no filaments from these nerves
to the gland, although they reach the investing capsule, as does also a
h from the descendens noni. Small filaments, derived from the pneumo-
ic and sympathetic nerves, descend, on the thyroid body, to the upper part
thymus. Sympathetic nerves also reach the gland along its various arteries.

the literature of the thymus, as well as many details of its comparative
ure, the reader is referred to a paper by Dr. H. Watney in the Phil. Trans.
882.

ORGANS OF DIGESTION.

The *digestive apparatus* consists of the *alimentary canal*, with various glands of which it receives the secretions.

The alimentary canal commences at the mouth and termina anus. Its average length is about thirty feet,—about five or the length of the body.

The part in the head and thorax consists of the *mouth*, with and *salivary glands*, the *pharynx*, and the *œsophagus* or gul part contained in the abdomen and pelvis consists of the *sto* the *small* and *large intestine*. Numerous small glands are si the mucous membrane of the alimentary canal, and the larger glands, the *salivary glands*, *pancreas* and *liver*, open on surface.

THE MOUTH.

The **mouth** is bounded by the lips, cheeks, tongue, and the soft palate, and communicates behind with the pharynx thr *fauces* (isthmus faucium). It is lined throughout by mucous m and into it open the ducts of the salivary glands.

The *lips* and *cheeks* are composed externally of skin, and int mucous membrane, between which are included muscles, ves nerves fully described in other parts of this work, areolar tissue numerous small glands. The free border of the lips is protec dry mucous membrane, which becomes continuous with the covered with numerous minute vascular papillæ (fig. 465)

Fig. 465.

Fig. 465.—THREE PAPILLÆ FROM THE LIP, BLOOD-VESSELS INJECTED (Toldt).

highly sensitive. In some of these papi end-bulbs, approaching in character t corpuscles, are found. On the inner s each lip, the mucous membrane forms the middle line, connecting the lip gums. These are the *frœna* or *frœn* of the upper lip is the larger.

Numerous small racemose glands (*labia* open on the inner surface of the lips ne aperture. They are situated between th membrane and the orbicularis oris muscles.

Other small glands (*buccal glands*) lie be buccinator muscle and the mucous membra cheek. Two or three, larger than the rest, tween the masseter and buccinator muscles, ing by separate ducts near the last molar called the *molar glands*. The secretion of these glands is understood to whether it has any of the specific properties of saliva is not know sebaceous glands occur on the outer part of the red border of the lips.

Immediately within the lips and cheeks are the *dental arches* ing of the teeth, gums, and alveolar borders of the maxillæ. (gingivæ) are composed of dense connective tissue, coher closely with the periosteum of the alveolar processes, and cove

ıd highly vascular mucous membrane, which is smooth in its ıl surface, but is beset with fine papillæ in the immediate vicinity teeth.

mucous membrane of the mouth is lined by scaly stratified epi-n, containing in the deeper layers numerous cells marked with and spines, like those described in the epidermis.

THE TEETH.

he human subject, as in mammalia generally, two sets of teeth heir appearance in the course of life, of which the first compre-the *temporary* or *milk* teeth, whilst the second is the *permanent* The temporary teeth are twenty in number, ten in each jaw, ıe permanent set consists of thirty-two, sixteen above and sixteen

GENERAL CHARACTERS OF THE TEETH.

ooth consists of three portions, viz., one which projects above the and is named the body or *crown*, another fixed in the alveolus or , the *root*, consisting of a *fang* or *fangs*—and a third, intermediate en the other two, and, from being more or less constricted, named *ck* (fig. 466). The size and form of each of these parts vary in fferent kinds of teeth.

e roots of the teeth are accurately fitted to the alveoli of the jaws, ich they are implanted. Each alveolus is lined by periosteum l periosteum, fig. 466, 4), which also invests the contained tooth h as the neck, and is blended above with the dense tissue of the . The fangs of all the teeth taper from the cervix to the point, his form, together with the accurate adjustment to the alveolus, he effect of distributing the pressure during use over the whole t, and of preventing it from unduly bearing on the point of the through which the blood-vessels and nerves enter.

e thirty-two permanent teeth consist of four incisors, two canines, bicuspids, and six molars in each jaw. The twenty temporary are four incisors, two canines, and four molars above and below. e are no bicuspids among the temporary teeth, the eight deciduous s preceding eight bicuspids of the permanent set. The relative on and arrangement of the different kinds of teeth in the jaws may pressed by the following formula, which also exhibits the relation en the two sets in these respects :—

		MO.	CA.	IN.	CA.	MO.		
Temporary teeth . . .	Upper	2	1	4	1	2	=10	=20
	Lower	2	1	4	1	2	=10	
		MO.	BI.	CA.	IN.	CA.	BI.	MO.		
Permanent teeth . . .	Upper	3	2	1	4	1	2	3=16	=32
	Lower	3	2	1	4	1	2	3=16	

E PERMANENT TEETH.—The **incisors** (fig. 467), eight in number, he four front teeth in each jaw, and are so named from being ed for cutting or dividing the food. Their *crowns* are chisel-d (*c*), and have a sharp horizontal cutting edge, which by con-d use is bevelled off behind in the upper teeth, but in the lower ones n down in front, where it comes into contact with the over-lapping of the upper teeth. Before being subjected to wear, the horizontal

edge of each incisor is marked by three small prominen
separated by two slight notches (fig 467, *d*). The anterior
the crown is slightly convex, and the posterior concave. Th

Fig. 466.

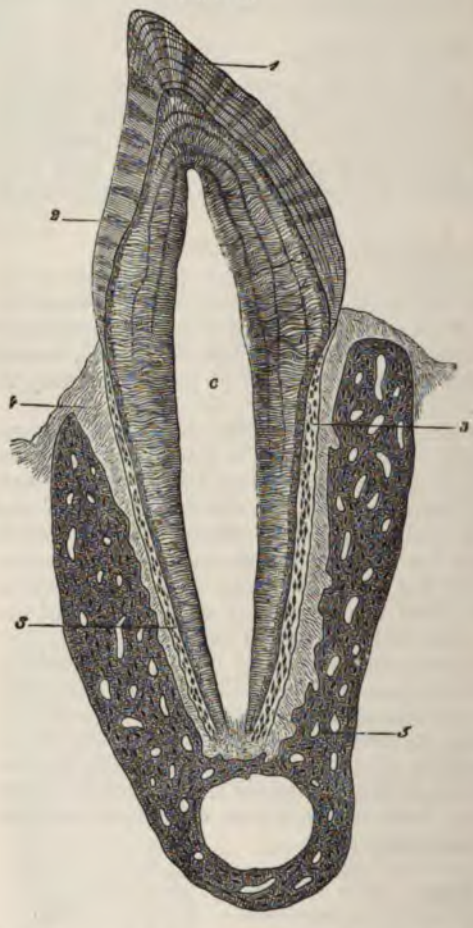


Fig. 466.—VERT
OF PREMOLAR
DIAMETERS (W

c, is placed i
cavity, opposite
neck of the toot
above is the crow
is the root (fang)
with radial an
markings; 2,
tubules and incre
3, cement or cr
with bone co
dental periosteu
of lower jaw.

long, single, c
compressed a
where it
though rarel
a slight l
furrow (as in

The lower i
are placed vert
jaw, but the c
upper teeth
obliquely forw
upper incisors
whole, larger th
ones. Of those
jaw the central
the larger; but
jaw, the centr
are the smalle
indeed, the sma
the incisor teeth

The **cani**
(fig. 468),
number, are pl
on each side,

below, next to the lateral incisors. They are larger and
than the incisor teeth. The *crown* is thick and conical, c
front and hollowed behind, and may be compared to th
large incisor tooth the angles of which have been remove
to leave a single central point or *cusp*, whence the name
applied to these teeth. The point always becomes worn d
use. The *fang* of the canine teeth is single, conical, and co
at the sides: it is longer than the fangs of any of the other te
is so thick as to cause a prominence of the alveolar arch: on the
is marked by a groove, an indication, as it were, of the cleft
sion which appears in the teeth next behind.

owing to its late appearance through the gum, is called the
tooth. The *crowns* of the molar teeth are low and cuboid in their
form. Their outer and inner surfaces are convex, but the cro
rather flattened before and behind. The grinding surface i
square in the lower teeth, and rhomboidal in the upper, the corne
rounded off; it bears four or five trihedral tubercles or cusps
the name *multicuspidati*), separated from each other by a cru
pression.

Fig. 469. Fig. 470.

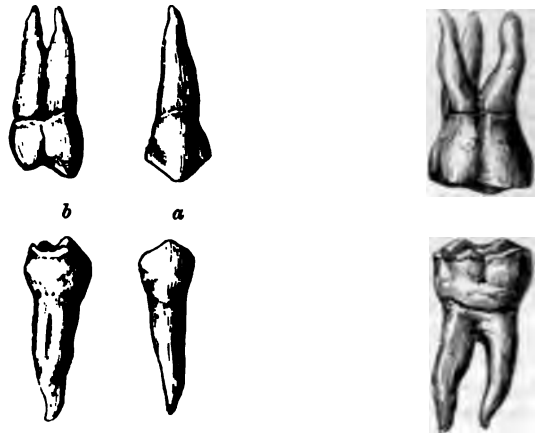


Fig. 469.—First bicuspid tooth of the upper and lower jaw.
a, front view; *b*, lateral view, showing the lateral groove of the fang, and
dency in the upper to division.

Fig. 470.—First molar tooth of the upper and lower jaws.
They are viewed from the outer aspect.

The bicuspid and the molar teeth, from the breadth and
character of their masticating surface, are fitted for bruising, c
and grinding the food.

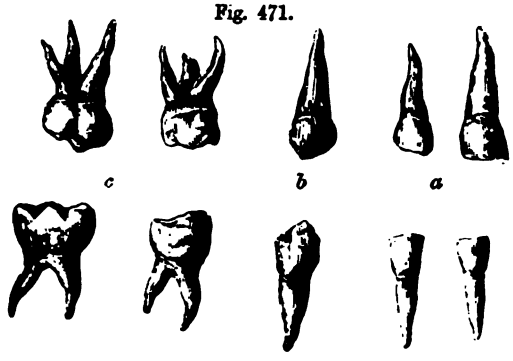
The *fangs* of the molar teeth are multiple. The upper molars have fo
situated at the angles of the masticating surface: of these the anterior
cusp is the largest, and is frequently connected with the posterior exter
by a low oblique ridge. In the upper wisdom-teeth, the two internal c
usually blended. The crowns of the lower molars, which are larger tha
of the upper, have five cusps, the additional one being placed between t
posterior ones, and rather to the outer side: this is especially evident
lower wisdom-teeth, in which, however, the crown is smaller and round
in the others. In the two anterior molars of the *upper* jaw, the fangs ar
in number, viz., two placed externally, which are short, divergent, and d
towards the antrum of the superior maxilla; and a third or internal fang,
is larger and longer, and is directed towards the palate, its posterior
extending as far back as that of the posterior external fang. This third f
often slightly grooved, especially when the two internal cusps of the crow
very distinct, and sometimes it is divided into two smaller fangs. Th
anterior molars of the *lower* jaw have each two broad, compressed fang
anterior, the other posterior, which are grooved on the faces that are t
towards each other, as if each consisted of two fangs fused together; they

nation or curve backwards in the jaw, and are slightly divergent, but
es parallel, or even nearly in contact with each other; more rarely one
f them is divided into two smaller fangs. In the wisdom-teeth of both
fangs are often collected into a single irregular conical mass, which is
rected backwards in the substance of the jaw, or curved irregularly; this
e fang sometimes shows traces of subdivision, and there are occasionally
ee in the lower tooth and three in the upper.
nge of teeth in each jaw forms a nearly uniform curve, which is not broken
nterval, as is the case in many mammals, and even in some of the Quad-

The upper dental arch is rather wider than the lower one, so that
h of the upper jaw slightly overhang those of the lower. While there
ht diminution in the height of the crowns of the teeth from the incisors
ds to the wisdom-teeth, there is in man no abrupt change of level along
re. In consequence of the large proportionate breadth of the upper
ncisors, the other teeth of the upper jaw are thrown somewhat outwards,
in closure of the jaws the canines and bicuspids come into contact partly
corresponding lower teeth, and partly with those next following; and
se of the molars, each cusp of the upper lies behind the corresponding
the lower teeth. Since, however, the upper molars and especially the
teeth are smaller than those below, the dental ranges terminate behind
t the same point in both jaws.

ILK-TEETH (fig. 471).—The temporary incisor and canine teeth resemble
the permanent set in their general form; but they are of smaller
ns. The temporary molar teeth present some peculiarities. The hinder

Fig. 471.



471.—MILK TEETH OF THE RIGHT SIDE OF THE UPPER AND LOWER JAWS.
a, the incisors; *b*, the canines; *c*, the molar teeth.

two is much the larger; it is the largest of all the milk-teeth, and is
ren than the second permanent bicuspid, which it afterwards gives place
first upper milk molar has only three cusps, two external and one
; the second has four. The first lower temporary molar has four cusps,
second five, of which in the latter case three are external. The *fangs* of
porary molars resemble those of the permanent set, but they are smaller,
more divergent from the neck of the tooth.

STRUCTURE OF THE TEETH.

naking a section of a tooth, it is found to be hollow within (fig.
The form of the cavity bears a general resemblence to that of
th itself; it occupies the interior of the crown, and extends along
ng, at the point of which it opens by a small orifice. In the
teeth the cavity is prolonged above into two fine canals, which
l one to each corner of the crown; in the bicuspid and molar teeth
nces a short *distance into each cusp.* In the case of a root formed

by the blending of two or more fangs, each division has a separ
prolonged to its apex.

Pulp of the teeth.—The central cavity of a tooth is called t
cavity, because it is occupied by a soft, highly vascular, and
substance, called the *dental pulp*. This pulp consists of
connective tissue containing cells, blood-vessels and nerves, and
fibres. The cells are partly disseminated in the matrix, and pa
a stratum at the surface of the pulp, where they are elongate
what like the cells of columnar epithelium (see fig. 484, *c*, p. 55
superficial cells (*odontoblasts*) send processes into tubules in the
to be afterwards noticed, of which more than one may come
same cell. The filaments within the tubules were first noticed by J
The arteries and nerves, which are derived from the internal
and fifth pair respectively, enter by the aperture at the point
fang. The vessels form a capillary network beneath th

Fig. 472.

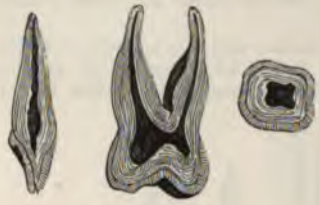


Fig. 472.—Sections of an incisor
tooth.

ficial cells ; the nerves, as desc
Boll in the rabbit's incisor, en
non-medullated fibres which
tributed abundantly at the su
the pulp and run up betw
superficial cells. Some appea
the direction of those cell-
which enter the hard tissue,
have not with certainty been traced into the dentinal tubules.

According to Klein it is not the odontoblasts but other more deeply l
which send processes into the tubules of the dentine. To this it may be
that in the developing tooth it is not difficult to trace the filaments into
toblasts themselves.

Hard tissues of the teeth.—The hard part of a tooth is c
of three distinct substances,—viz., the proper dental substan
or *dentine*, the *enamel*, and the *cement* or *crusta petrosa*. The
constitutes by far the larger portion ; the enamel is found o
the exposed part or crown ; and the cement covers with a thin
surface of the fang.

The **dentine** (Owen,) resembles bone in its general asp
chemical constitution, but is not identical with it in structure.

The dentine of human teeth is composed of 28 parts per cent. of an
72 of earthy matter. The former is resolved into gelatin by boiling.
position of the latter, according to Bibra, is as follows, viz., phospha
66·7 per cent., carbonate of lime 3·3, phosphate of magnesia and other
cluding a trace of fluoride of calcium, 1·8. Berzelius found 5·3 carbonat

The dentine is penetrated throughout by fine tubes, whi
nearly parallel, give it a striated aspect (fig. 466). When a thi
is viewed under the microscope by transmitted light, the solid s
or matrix, is transparent and apparently homogeneous, while t
being (in a dried specimen) filled with air, are dark : but when
reflected light on a dark ground, the latter appear white ;
respects they resemble lacunæ and canaliculi of bone.

The *dentinal tubules* open at their inner ends into the pul

minal branches of tubules are occasionally seen to pass on into the cem
covers the fang, and to communicate with canaliculi proceeding
characteristic lacunæ found in that osseous layer. Tubules have like
observed by Tomes passing into the enamel in the teeth of marsupial
and in a less marked degree, in human teeth.

Fig. 474.

Fig. 474.—Sections of dentinal tubules (after F
a, cut across; *b*, cut obliquely. (About 300 diam

The *intertubular substance* is translucen
animal matter which remains, after the e
been removed by an acid, may be torn int
(Sharpey), parallel with the internal surfac
pulp-cavity, and therefore across the directi
tubules. According to Ebner the matrix con
fibrils like those of the matrix of bone.

The laminated structure is an indication of the deposition of dentinal
in successive strata in the process of formation of the tooth—the lam
sponding with the shape of the pulp-surface at successive stages of th
Not unfrequently lines, varying in number and breadth, are seen in s
the dry tooth, conforming in direction with the lamination just spoken

Fig. 475.

Fig. 475.—Vertical section of
part of an incisor tooth (fro
magnified 7 diameters.
a, the pulp-cavity; *b*, dentine
incremental lines; *d*, cement;
with bands indicating the direct
ranges of fibres; *f*, coloured lin
enamel.

Fig. 476.

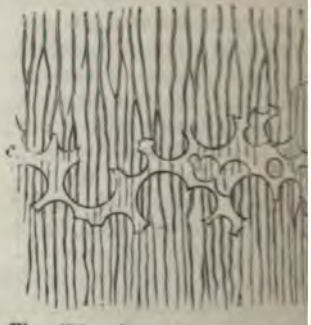


Fig. 476.—A small portion of
tine with interglobular spa
Kolliker). 350 diameters.
c, portion of incremental line
the interglobular spaces, which are
up by the transparent material used
ing the specimen.

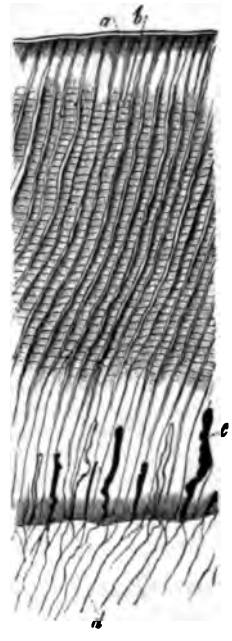
mental lines, Salter, fig. 475, *c*). They are caused by the drying of imperf
cified dentine, which shows little cavities bounded by, and therefore
their figure from, minute nodules or globules of dentine, and hence nam
globular spaces (fig. 476, *c*). The interglobular spaces, and the glob

hem, vary in size within wide limits. A layer, in which they are very *ular layer* (fig. 473, 2)—is not uncommonly found towards the outer the dentine.

namel is that hard white covering which encrusts and protects sed portion or crown of a tooth. It is the hardest of all the ssues, but is gradually worn down by protracted use. It is on the grinding surface and cutting edge of the teeth, and be-adually thinner towards the neck, where it ceases.

ng to Bibra, it contains of earthy constituents 96·5 per cent., viz., of lime with traces of fluoride of calcium 89·8, carbonate of lime 4·4, of magnesia and other salts 1·3, and of animal matter only 3·5 per rzelius, however, gives the proportion of carbonate of lime as 8, and matter as only 2 per cent..

Fig. 477.



-THIN SECTION OF THE ENAMEL AND A PART DENTINE (from Kolliker). 350 DIAMETERS.

ılar pellicle of the enamel; *b*, enamel-fibres or ith fissures between them and cross striæ; *c*, he enamel communicating with the extremities the tubuli (*d*).

namel is made up entirely of very hard e microscopic columns or prisms, ar-losely together, side by side, and set by emity upon the subjacent surface of the (fig. 477). The columns are disposed in which, on the grinding surface, are set y, but on the sides of the crown get rizontal. Near the dentine the prisms e another in the alternate ranges, but parallel as they approach the surface of h; from this intercrossing the effect alternate light and dark stripes is ob-s in figs. 466 and 475). A series of con-ines is likewise to be seen crossing the ibres: these are termed *coloured lines* eir brown appearance, but whether y pigmentary deposit or otherwise is ained. Minute fissures not unfrequently the deep part of the enamel, which run clusters of the prisms down to the sur-the dentine (fig. 477, *c*); and other much larger and more fissures are often observed leading down from the depressions ces between the cusps of the molar and premolar teeth. The surface of the enamel is finely striated.

amel-columns (fig. 478) have the form of solid six-sided prisms. iameter is ordinarily about $\frac{1}{5000}$th of an inch. They are by alternate dark and light transverse shadings, which are to be due to the existence of shallow constrictions along the The inner ends of the prisms are implanted in minute hexagonal ns found on the surface of the dentine; whilst the outer ends and present, when examined with a high magnifying power, a l appearance *(fig. 478, B)*. The prisms are united by a small

amount of a substance which appears similar to the intercellular subst of an epithelium, but is probably calcified. In the outer part enamel there are some shorter prisms interpolated between the othe

When submitted to the action of dilute acids, the enamel is almost en dissolved, and leaves scarcely any discernible traces of animal matter. centre of the prisms is first dissolved, showing this part to be less calcified than the periphery. By the action of an acid, the enamel of formed or still growing teeth may be broken up, and its structural el more easily distinguished.

Fig. 478.

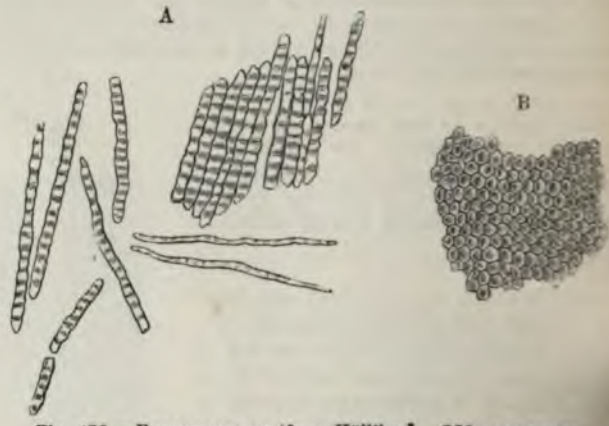


Fig. 478.—ENAMEL-PRISMS (from Kölliker). 350 DIAMETERS.

A, fragments and single columns of the enamel, isolated by the action of hydrochlori
B, surface of a small fragment of enamel, showing the hexagonal ends of the prism

It is further found, on treatment with acid, that a very thin membrane (*cuticle*) entirely covers the enamel of unworn teeth upon its outer surface 477, *a*). This membrane forms a protective covering to the enamel. It is of epithelial and horny nature, and withstands prolonged boiling as well as action of acids and other re-agents. According to Tomes, this membran rather of the nature of cement, but without lacunæ. On this supposition, h ever, it is difficult to understand the meaning of the epithelial markings wh are produced in it after the action of nitrate of silver.

The **crusta petrosa or cement** is the third substance wh enters into the formation of the teeth. This is a layer of true bo slightly modified in structure, and investing that part of the dent which is not protected by the enamel. It covers the whole fa towards the lower end of which it becomes gradually thicker, and specially developed at the apex, and along the grooves of the compo fangs. As life advances, the cement generally grows thicker, especi near the point of the fang, where it sometimes blocks up the ori leading to the pulp-cavity.

The crusta petrosa is lamellar in structure, and contains lacunæ canaliculi resembling those of bone but larger and more irregular (473, 1). Where the cement is very thick it may contain Havers canals. On the milk teeth the cement is thinner, and contains fe cells. Perforating and decussating fibres, similar to those of ordin bone, occur in the cement.

its deeper portion, or extended by further growth, into as many distinc
tions of cells, or **special enamel-germs**,—one for each tooth—of a cl
shape, connected by a narrowed neck with what remains of the commo
ingrowth (fig. 480, *f'*). These tooth-germs, as they may now be
lodged each in its own recess, which at this time is merely a pit
embryonic tissue, without the membranous coats which afterwards a
From the bottom a **papilla** (fig. 481, *p*) meanwhile rises, soon bec
cular, and assuming the shape of the future tooth-crown. It is rec
corresponding dimple of the enamel-germ, which now comes to resem
an inverted cup, and fits upon the papilla (fig. 481, A, *f'*).

Fig. 481.

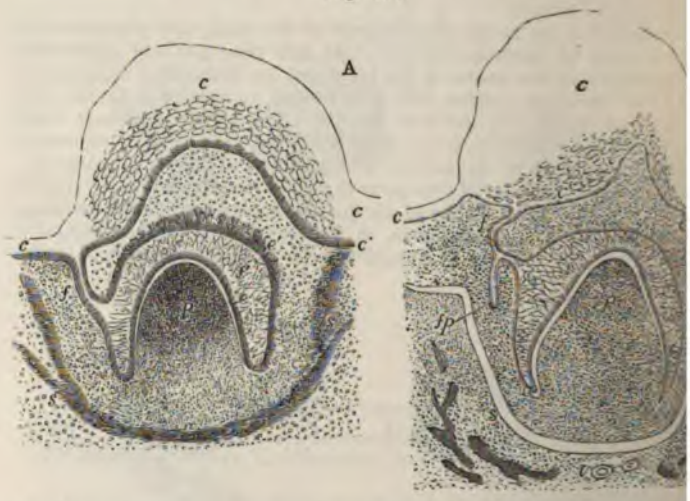


Fig. 481.—SECTIONS AT LATER STAGES THAN fig. 480 THE PAPILLA HAVING BECOM
AND INDENTED THE ENAMEL-GERM, WHICH HAS AT THE SAME TIME GROW
ROUND IT. (from Kölliker).

c, epithelium of gum, sketched in outline, *f*, neck of enamel-germ, *f'*, enamel-or
deeper columnar cells ; *c'*, projections into the corium ; *p*, papilla ; *s*, dental sa
In B, the enamel-germ, *fp* of the corresponding permanent tooth has become form

The included enamel-germ is next cut off from connection with the su
epithelium, by obliteration of the neck of communication.

According to Goodsir the order in which the papillæ become distinct is ver
That of the anterior milk molar is the first (7th week) ; that of the canine
week) ; the incisor papillæ next (9th week), the central before the lateral ;
of the posterior milk molar last (10th week). The several papillæ of
jaw appear a little earlier than the corresponding ones of the lower.
sixteenth week there grows downwards and backwards from the narro
each follicle, an epithelial bud, soon becoming elongated and swelling
bottom into a flask-shape. These are the germs of the ten anterior p
teeth as will be afterwards shown.

While the above described changes are going on, the soft embryo
bounding the depression which contains the enamel-germ, becomes
into a vascular membranous sac (*dental sac*). This originates from a p
same somewhat dense submucous tissue that gives rise to the dental papi
479), and the whole is supported by the osseous maxilla as soon as this is
The jaw is at first in the form of a bony gutter, in which the teeth
are lodged ; but this is soon divided by osseous partitions into chambe

ooth-sacs, at first with wide openings, which afterwards are narrowed, to allow the contained sacs to cohere with the gum along the border of . The alveoli are formed subsequently around the fangs of the teeth as come developed, and the jaw is deepened by the growth of its alveolar

ental sacs are well seen in the jaw of an infant a few months old, he eruption of the teeth. They are represented at this stage in fig. 482. nsist of an outer fibro-vascular coat connected with the periosteum, and highly vascular layer with a little jelly-like tissue interposed between . The inner coat is lined with the epithelium of the enamel organ to be er described. Their blood-vessels are derived partly from the dental which course along the base of the sacs, and partly from those of the Their extreme vascularity doubtless has relation to the nutrition of the organ.

Fig. 482.

2.—THE DENTAL SACS ED IN THE JAW OF A AT BIRTH.

e left half seen from er side; *b*, the right en from the outer part of the bone has moved so as to ex- e dental sacs as they w the gum; the lower hows the sacs of the eth and the first per- molar, exposed by g the bone from the ; the upper figure he same from the in- gether with the sacs permanent incisor and teeth adhering to the

papillæ, now become the dental pulps, acquire a perfect resemblance to the s of the future teeth, and then the formation of the hard substance com- s in them, as will be immediately described. This process begins very early. y the end of the fourth month of fœtal life thin shells or caps of dentine 3) are found on all the pulps of the milk-teeth, and a little later on that first permanent molar, while at the same time the coating of enamel begins leposited on each.

cap of dentine increases in extent by a growth around its edges, and in

Fig. 483.

83.—DIFFERENT STAGES IN THE FORMATION OF AN UPPER MOLAR TOOTH WITH TWO FANGS (from Blake).

he distinct caps of dentine for five cusps in the earliest stage of formation; in 2, e remaining figures, the crown is downwards; in 2, and 3, the formation of the having proceeded as far as the neck, a bridge of dentine stretches across the base tooth-pulp; and in 4, the division of the fangs is thus completed; in 5, 6, and extension takes place *in the fangs*.

thickness by additions in its interior, while the substance of the pulp de
proportion. This growth of the tooth continues until the crown is com
its proper width, and then the pulp undergoes a constriction at its base
the cervix of the tooth, and afterwards elongates and becomes narrower,
serve as the basis of the fang. Sooner or later, after the completion of t
this part of the tooth appears through the gum, whilst the growth of d
complete the fang is continued at the surface of the elongating pul
gradually becomes encroached upon by successive formations of hard s
until only a small cavity is left in the centre of the tooth, containing
but the reduced pulp, supplied by slender threads of vessels and nerv
enter by a small aperture left at the point of the fang after the dentin
pleted. In the case of teeth having complex crowns and more than a sin
the process is somewhat modified. On the surface of the dental pulp
tooth, as many separate caps or shells of dental substance are formed as
eminences or points; these soon coalesce, and the formation of the t
ceeds as before as far as the cervix. The pulp then becomes divided in
more portions, corresponding with the future fangs, and the ossification
in each as it does in a single fang; while, at the same time, a horizo
jection or bridge of dentine is deposited across the base of the pulp, bet
commencing fangs, so that if the tooth be removed at this stage and
on its under surface, its shell presents as many apertures as there are
fangs (fig. 483, 3 and 4). In all teeth, the pulp originally adheres by
base to the bottom of the sac; but, when more than one fang is to be d
the pulp is, as it were, separated from the sac in certain parts, so that it
adhere at two or three insulated spots only, corresponding with the fan
the dentine continues to be formed along the surrounding free surfa
pulp.

Formation of the hard tissues of the Teeth.—The account already
the structure of the permanent pulp of a tooth will apply also to tha
papilla or formative pulp of the growing tooth, both before and after th

Fig. 484.

Fig. 484.—PART OF SECTION OF
ING TOOTH OF A YOUNG RAT
THE MODE OF DEPOSITION OF
TINE. HIGHLY MAGNIFIED.

a, outer layer of fully formed
b, uncalcified matrix, with
nodules of calcareous matter
cified part; *c*, odontoblasts
cesses into the dentine; *d*,
section is stained with carmi
colours the uncalcified matrix,
the calcified part.

has begun to be formed from it. The capillary vessels, which form a
loops a short distance beneath the surface, are much more abundant opp
point or points where calcification is about to commence.

The **dentine** is produced more immediately by the elongated cells (odon
already described as forming the superficial stratum of the pulp (fig.
These cells send out from their free extremities filamentous processes, as
by Lent, and the matrix or intertubular substance of the dentine, whic
bably shed out by the odontoblasts, becomes formed simultaneously betw
around these processes and is thus as it were moulded upon them, so as
the tubules in which the cell-processes are now enclosed. The same
continue to spin out a filament until the tubule is completed in its whole
and in many cases a cell sends out two or more processes, coalescing
as the cell recedes, the branched tubules being thus produced.

The collogenous basis of the dentinal matrix is at first uncalcified (fig.
but the material of calcification soon begins to be deposited in nodules or

together into a uniform hard substance (*a*). In parts where this co-
artially fails the uncalcified matter between the globules shrinks up
oth has become dry, so as to leave the interglobular spaces previously
. 552). The globular mode of deposition is indicated also by the inner
the growing dentine, which is nodulated (Czermak); and, indeed,
odules may be seen in the soft tissue of the growing matrix (see

Fig. 485.

A SECTION THROUGH THE ENAMEL ORGAN
AL SAC FROM THE TOOTH OF A CHILD AT
m Kölliker). 250 DIAMETERS.

lense layer of the dental sac; *b*, inner
re of the same with capillary blood-
a somewhat denser layer towards the
n; *c*, spongy substance; *d*, inner colum-
nd *e*, outer cubical cells of the enamel

ng to Waldeyer the protoplasm of
comes directly transformed into the
atrix, except the central part, which
naltered, occupying the tubule, and
d by another cell lying deeper in the
which the first is in connection,
in succession. This view has been
by Beale, Boll, Tomes, Klein, and
rities, but in my opinion it is scarcely
'or if it were true we should expect
ontoblasts which had only partly
the transformation in question, and
have never been described. We
ther expect to find in the matrix
its coalesced formative cells, but
have never been discovered in it.
over very difficult to explain the
of the tubules if we accept Wal-
w. Indeed this hypothesis seems to
like the similar views with regard
mation of connective tissue and
p. 71-2 and 104-5) largely upon theo-
siderations, and to be opposed rather
rted by the known facts of the case

amel.—The surface cells of the
m line the dental sac in the form of
or cubical epithelium (fig. 485, *e*).
er hand the cells which lie next the
the pulp become elongated and
into a prismatic shape, precisely like
epithelium (*d* fig. 485). The central
go a remarkable change. Originally
they for a time merely increase in
ut soon, assuming a stellate form,
out branches which join with one
. 485, *c*), whilst a clear fluid or jelly-
collects in their interstices.

cavity containing the enamel-germ numerous small papillary
f the vascular sac and adjacent mucous membrane project, and
hese, on the other hand, epithelial processes extend from the
m into the membrane (fig. 486, 3). The enamel-germ is now designated
el organ," *organon adamantinæ* of Purkinje, who named the columnar

epithelium on the surface of the pulp the *membrana adamantinæ*, or membrane."

The enamel-prisms appear to be formed by the columnar cells of th organ, either by direct calcification of their substance or by deposition the former, since cells partly converted into hard substance have been o

Fig. 486.

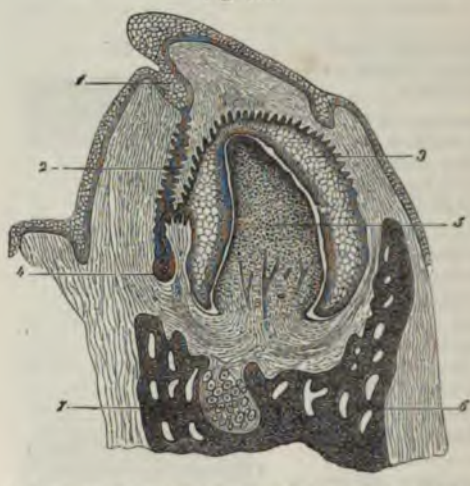


Fig. 486.—Sectio THE LOWER J HUMAN FŒTUS, METERS LONG (deyer). ³⁄₁

1, dental groov by epithelium cont that lining the remainder of the enamel-germ ; organ ; papilliform are seen extending the upper part of sac; 4, enamel germ responding perma the space in whi closed forms Good of reserve ; 5, denti 6, lower jaw-b Meckel's cartilage.

C. Tomes. The cells meanwhile may be supposed to grow continually a end. In sections a space is observed between the cells and the new enamel, but this is probably produced after death by a shrinking of the The process of formation commences next to the forming dentine, almo indeed as the latter begins to be produced. The enamel substance soft and friable. The enamel-organ extends no farther than the crow tooth, to which, therefore, the deposit of enamel is limited. As t tion of enamel becomes completed the rest of the enamel-organ away : the superficial tesselated layer is believed to become the dentis."

The **cement** begins to be formed, simultaneously with or soon after t of the fang, by the subperiosteal tissue, as in the formation of the layers of a bone.

Eruption of the temporary Teeth.—At the time of birth the crow anterior milk-teeth, still enclosed in their sacs, lie in bony crypts in the somewhat narrowed mouths opening on its edge. Their appearance th gums follow a regular order, but the period at which each pair of teeth is within certain limits. The eruption commences about the age of seve and is completed about the end of the second year. It begins with th incisors of the lower jaw (about the sixth to the ninth month), w followed, after a resting period of two or three months, by the incis upper jaw. Then after a rest of a few months come the lower later and the first molars ; then after four or five months the canines, and fin the second year the second molars.

The eruption of the tooth is preceded by absorption of part of the wall of cavity in which it lies, especially of the front part, so as to leave a wide for the emergence of the crown. After this a redeposition occurs ar neck of the tooth, and this deposition is continued around the fangs as becoming formed ; in this way the bony socket is produced.

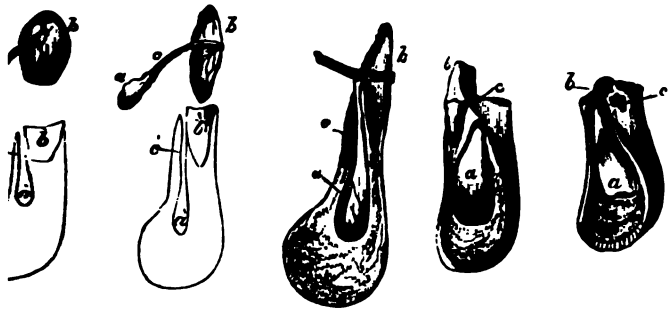
Before the teeth protrude through the gum, this undergoes some changes : its edge at first becomes dense and sharp, but, as the tooth ap it, the sharp edge disappears, the gum becomes rounded or tumid, and

hue ; the summit of the tooth is seen like a white spot or line through lar gum, and soon afterwards emerges. Before the eruption, the mucous e is studded with a number of small white bodies, which were described s as glands (*dental glands*). They are little nests of epithelium-cells) and appear to be portions of the epithelium of the enamel-germ which ped obliteration. Similar bodies are found in other situations where m is included in a seam, and is undergoing obliteration, as along the line e of the palate (Epstein).

pment of the permanent Teeth.—Ten permanent teeth in each jaw he milk-teeth, and six are superadded further back in the jaw. It will nient to treat first of the ten anterior teeth or *teeth of succession.*

ics and pulps of these teeth have their foundations laid before birth hose of the milk set. It will be remembered that behind each milk- here is formed about the sixteenth week a small epithelial growth (fig. ; fig. 486, 4), derived from the neck of the enamel-germ, and this forms el-germ of the corresponding permanent tooth. They are ten in number aw, and are formed successively from before backwards. These germs grate and recede into the substance of the gum behind the germs of the

Fig. 487.



7.—SKETCHES SHOWING THE RELATIONS OF THE TEMPORARY AND PERMANENT DENTAL SACS AND TEETH (after Blake, with some additions).

wer parts of the first three figures, which are somewhat enlarged, represent f the lower jaw through the alveolus of a temporary incisor tooth : *a*, indicates the permanent tooth ; *c*, its pedicle ; *b*, the sac of the milk tooth or the milk lf ; *a'*, *b'*, indicate the bony recesses in which the permanent and temporary lodged, and *c'*, the canal by which that of the former leads to the surface of the nd the alveolus of the temporary tooth. The fourth and fifth figures, which are the natural size, show the same relations in a more advanced stage, in IV., o the change of teeth, in V., when the milk tooth has fallen out and the per- oth begins to rise in the jaw ; *c*, the orifice of the bony canal leading to the he permanent tooth.

th. In the meantime, a papilla is formed at the bottom of each enamel- nat for the central incisor appearing first, at about the sixth month,) and s become each inclosed within a dental sac, the sac of the permanent bering to the back of that for the temporary tooth. The bony socket not as a cell for the reception of the milk-sac, but also a small posterior recess for the permanent tooth-sac, with which the recess keeps pace in its In the lower jaw, to which our description may now, for convenience, ued, the permanent sac is at length found at some distance below and he milk-tooth ; the sac for the permanent tooth acquiring at first a e, and being then connected with the gum by a solid pedicle of fibrous g. 487, I., II., *c*). *The recess in the jaw* (*a'*) has a similar form, drawn

out into a long canal for the pedicle, which opens on the edge of the jaw an aperture behind the corresponding milk-tooth. The permanent tooth is separated from the socket of the milk-tooth by a bony partition, which, as as the root of the milk-tooth just above it, becomes absorbed as the crown the permanent tooth rises through the gum. When this has proceeded far enough the milk-tooth becomes loosened, falls out or is removed, and the permanent tooth takes its place. The absorption of the dental substance commences near the ends of the fangs, and proceeds upwards until nothing but the crown remains. The cement is first attacked, and then the dentine: but the process is similar in the two tissues. The change is not produced merely by pressure, but, as in the case of the absorption of bone, through the agency of multinucleated absorbing cells or osteoclasts, developed at the time, and applied to the surface of the fang. The sockets begin to be formed around the neck of the tooth as soon as the crown projects, and are formed simultaneously with the developing fangs.

Fig. 488.

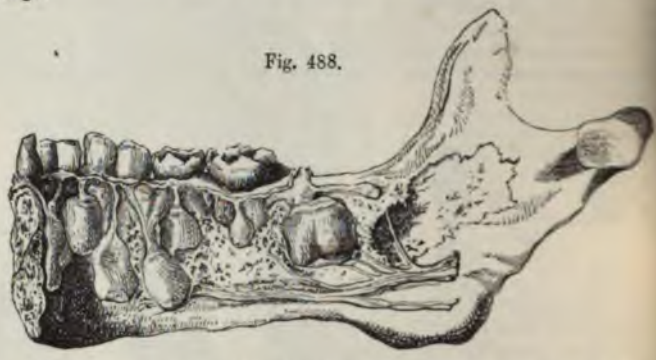


Fig. 488.—PART OF THE LOWER JAW OF A CHILD OF THREE OR FOUR YEARS OLD, SHOWING THE RELATIONS OF THE TEMPORARY AND PERMANENT TEETH.

The specimen contains all the milk-teeth of the right side, together with the incisors of the left; the inner plate of the jaw has been removed, so as to expose the sacs of all the permanent teeth of the right side, except the eighth or wisdom tooth, which is not yet formed. The large sac near the ramus of the jaw is that of the first permanent molar, and above and behind it is the commencing rudiment of the second molar.

The six posterior (or *superadded*) permanent teeth, that is, the three permanent molars on each side, do not come in the place of other teeth. They arise from successive extensions of the enamel-germ carried backwards in the jaw behind the milk-teeth.

The part of the common enamel-germ posterior to the last temporary molar long continues unobliterated, and from it there becomes developed at about the fifteenth week of embryonic life a special enamel-germ which forms the rudiment of the first permanent molar tooth. After a long interval, viz., about the seventh month after birth, the germ for the second permanent molar tooth appears projecting backwards from the neck of that for the first molar. After another long interval, during which the sac of the first permanent molar and its contained tooth have acquired great size, and that of the second molar has also advanced considerably in development, the same changes once more occur and give rise to the sac and papilla of the wisdom-tooth (third year). The subsequent development of the permanent molar teeth takes place within their sacs just like that of the other teeth.

Calcification begins first in the anterior permanent molar teeth. Its order and periods may be thus stated for the upper jaw, the lower being a little earlier. First molar, five or six months after birth; central incisor, a little later; lateral incisor and canine, eight or nine months; two bicuspids, two years or more; second molar, five or six years; third molar, or wisdom-tooth, about twelve years.

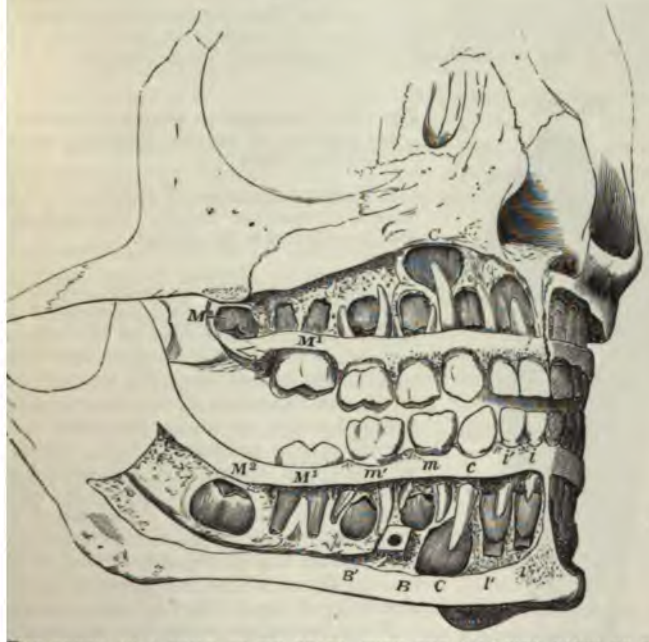
of the permanent Teeth.—The time at which this occurs in regard of teeth in the lower jaw is exhibited in the subjoined table. The ng teeth of the upper jaw appear somewhat later.

ır, first	6 years.
sors, central	7 „
, lateral	8 „
ıspids, anterior	9 „
„ posterior	10 „
ines	11 to 12 „
ars, second	12 to 13 „
, third (or wisdom)	17 to 25 „

before the shedding of the temporary incisors—*i.e.*, about the sixth there is the greatest number of teeth in the jaws. At that period ll the milk-teeth, and the crowns of all the permanent set except the th, making forty-eight (see fig. 489).

he growth of the teeth the jaw increases in depth and length, and changes in form. In the child it is shallow, but it becomes much he adult. In the young subject the alveolar arch describes almost the a circle; but in the adult the curve is semi-elliptical. The increase s place in the length of the jaw arises from a growth behind the posi-

Fig. 489.



THE TEETH OF A CHILD OF SIX YEARS, WITH THE CALCIFIED PARTS OF THE ANENT TEETH EXPOSED (after Henle and modified from nature, A. T.).

e of the teeth of the right side are shown, together with the three front teeth ide: in the upper and lower jaws the teeth are indicated as follows, viz.:— —*i*, inner or first incisor; *i'*, outer or second incisor; *c*, canine; *m*, first second molar. 2, *permanent-teeth*—I, inner or first incisor; I', outer or or; C, canine; B, first bicuspid; B', second bicuspid; M^1, the first molar, assed through the gums; M^2, the second molar, which has not yet risen above the third *molar is not yet formed.*

tion of the milk-teeth, so as to provide room for the three additio each side belonging to the permanent set. At certain periods in t the jaws there is not sufficient room in the alveolar arch for the gr the permanent molars; and hence the latter are found enclosed the coronoid process of the lower jaw, and in the maxillary tub upper jaw, but they afterwards successively assume their ultima the bone increases in length. The space taken up by the ten anter teeth very nearly corresponds with that which had been occupied by teeth; the difference in width between the incisors of the two se pensated for by the smallness of the bicuspids in comparison w molars to which they succeed. Lastly, the angle formed by the ra of the lower jaw differs at different ages; thus it is obtuse i approaches nearer to a right angle in the adult, and again beco obtuse in old age (see Vol. I.).

SECONDARY DENTINE.

Under this head are included certain varieties of hard tissue liab in the pulp-cavity of a tooth after the regular production of the d pleted. The two chief kinds hitherto described, are the following

1. **Osteodentine** (Owen).—This is a hard substance which some deposited within the pulp-cavity, somewhat resembling bone in st traversed by canals, which contain blood-vessels and pulp-tissue, a rounded by concentric lamellæ like the Haversian canals of bone canals, numerous tubules radiate, larger than the canaliculi of bo in this respect, and also in their mode of ramification, the tubes It may or may not coalesce with the previously formed dentine.

Fig. 490.

Fig. 490.—Longitudinal section of incis ing dentine of repair. Slightly m duced from Salter.)

d, *d'*, denuded surfaces of dentine; *r*, deposits of secondary dentine. Two or th lines are observed in the dentine.

2. **Dentine of Repair** (Salter).—Wh surface of the dentine becomes denude so that the peripheral ends of the tu exposed, as may happen in the crown wear of the enamel, or at the cervix f friction and abrasion of the cement, a dentinal matter occurs on the inner dentine exactly corresponding in positi with the area occupied by the centra exposed tubules. Many of the affected t subsequently filled up by a deposit o within them, so that on section both dentine and the corresponding part o dentine appear clearer and more transp remainder of the dentinal substance (se

When the surface-injury has been co dentine of repair is largely in excess, an cases completely fill up the pulp-cavity.*

* In some of the lower animals other kinds of dentine are found; for these, and many other details regarding the structure and development of could not conveniently be introduced here, the student is referred t "Manual of Dental Anatomy" by C. S. Tomes, F.R.S.

ent Literature of the Teeth.—*Waldeyer*, in Stricker's Handbook, 1870; *Koll-* Ue. Linien in Schmeltz u. Cement, München Sitzungsb., 1871; Zahnbein, Schmeltz ment, Zeit. f. wiss. Zool. XXIII.; *C. S. Tomes*, on the cuticula dentis, Qu. J. micr. 872; On the dev. of the teeth, same journal, 1876; On vascular dentine, Proc. oc., 1877, and Phil. Trans., 1878; *Magitot et Legros*, Follicule dent. chez les if., J. de l'anat., 1873; *Salter*, Dental Pathology, 1874; *Magitot*, Determ. de &c., Compt. rend. LXXVIII., 1874; Struct. et dev. du tiss. dent., Compt. rend., 1880; *Lambert*, in Bull. de l'acad. roy. de Belg., XLIII., 1877 (teeth of diff. races nkind); *Epstein*, Ue. Epithel-perlen, &c., in Zeitschr. f. Heilk., I., 1880. The literature will be found at the end of Waldeyer's article in "Stricker's Handbook," ther references in Tomes' "Dental Anatomy."

THE TONGUE.

he **tongue** is a muscular organ covered with mucous membrane. eriorly it is connected with the hyoid bone, and the back part of its r surface forms the floor of the arch of the fauces; inferiorly it ves from base to apex the fibres of the genio-glossus muscle, and igh the medium of that muscle is attached to the lower jaw.

ucous membrane.—On the *under surface* of the tongue the ous membrane is smooth and thin. It forms a fold in the middle called the *frænum linguæ*, in front of the anterior border of the genio- i muscles. On each side below, as the mucous membrane passes the tongue to the inner surface of the gums, it covers the sublingual d. In front of the frænum, the ranine vein may be distinctly seen ch side through the mucous membrane, and close to it lies the ranine y. Further out is an elevated line with a fimbriated margin directed ards, which extends to the tip. The ducts of the right and left axillary glands end by papillary orifices close together, one on each of the frænum; and further back, between the sides of the tongue the lower jaw, are the orifices of the several ducts belonging to the ngual glands.

he *upper surface* or *dorsum* of the tongue (fig. 491), is convex in its ral outline, and is marked along the middle for nearly its whole th by a slight furrow called the *raphe*, which indicates its bilateral metry. About an inch from the base of the tongue, the raphè n terminates in a depression, closed at the bottom, which is called *foramen cæcum* (Morgagni), and in which several small glands open. ee folds, named the glosso-epiglottic folds or frænula, of which the dle one is the largest (frænum epiglottidis), pass backwards from base of the tongue to the epiglottis.

apillæ.—The upper surface of the tongue in front of the foramen um (the anterior two-thirds) is covered with small eminences named *llæ*. They are found also upon the tip and borders, where, however, gradually become smaller, and towards its under surface they ppear. The papillæ are of three kinds, *circumvallate*, *fungiform* and *al*, varying both in size and form, but all of them visible to the ed eye; they themselves, like the rest of the mucous membrane of tongue and mouth generally, are covered with closely set, microscopic ndary papillæ hidden under the epithelium, which correspond with e of the skin, and are each occupied by a long loop of capillary blood- els. Lymphatics also originate within the papillæ and pass as else- re in the mouth into a superficial plexus in the mucous membrane, n which again the lymph is conveyed away by valved vessels seated he submucous tissue.

Papillæ.—The large **circumvallate papillæ** (fig. 491, 1, 2), from seven to twelve in number, are found on the back part of the tongue arranged in two rows, which run obliquely backwards and inwards,

Fig. 491.

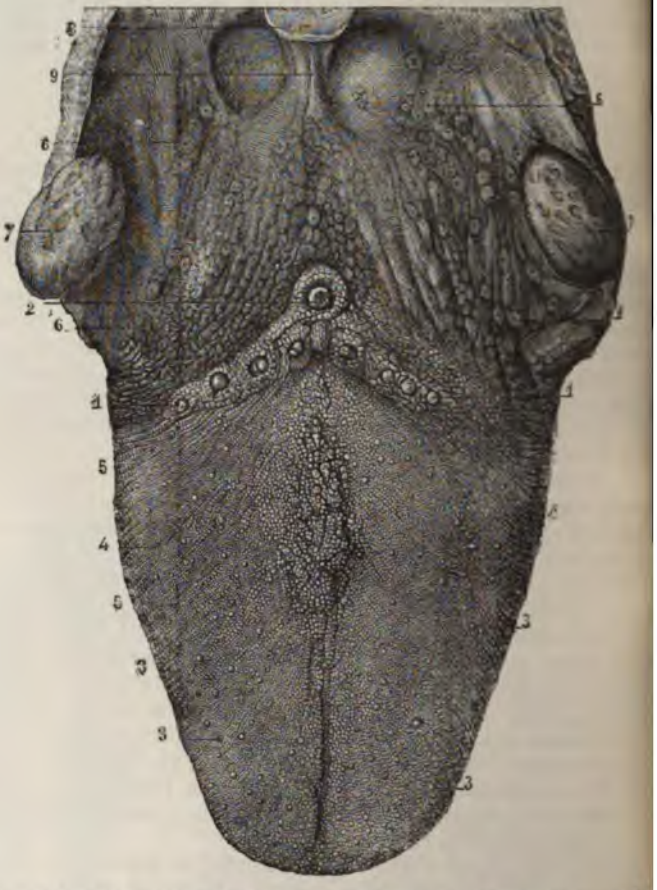


Fig. 491.—Papillary surface of the tongue, with the fauces and tonsils (from Sappey).

1, 2, circumvallate papillæ; in front of 2, the foramen cæcum; 3, fungiform papillæ; 4, filiform and conical papillæ; 5, transverse and oblique ranges; 6, mucous glands at the base of the tongue and in the fauces; 7, tonsils; 8, part of the epiglottis; 9, median glosso-epiglottic fold or frænum epiglottidis.

meet towards the foramen cæcum, like the arms of the letter V. They are situated in cup-like depressions of the mucous membrane, and have the shape of a truncated cone, of which the smaller end is attached to the bottom of the cavity, and the broad flattened base appears on the surface (fig. 492). They are therefore surrounded by a circular trough (*fossa*), around which again is an annular elevation of the mucous mem-

vallum), and in some of them there is found a central depression, ıich the ducts of one or more glands open. The stratified ım covering the papillæ vallatæ is thick, and completely conceals ınte secondary papillæ.

Fig. 492.

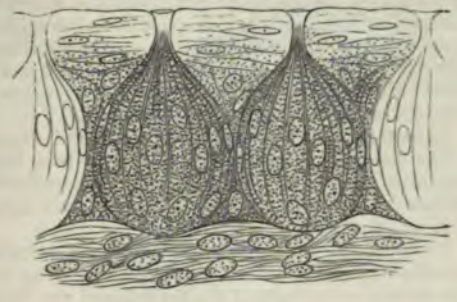
—VERTICAL SECTION OF CIR-LLATE PAPILLA FROM THE (Engelmann). 25 DIAME-

papilla ; B, the surrounding he figure shows the nerves of la spreading towards the sur- towards the taste-buds which dded in the epithelium at the the sulcus on the left the duct d is seen to open.

te-buds.—Forming a zone around the sides of the papilla, and and some animals upon the opposed wall of the vallum, are imbedded in this thick epithelium, peculiar ovoidal or flask-shaped composed of modified epithelium-cells and believed to be special of taste. These *taste-buds*, as they have been termed, are com- in form and structure to the leaf-buds of a plant (fig. 493). By ases they are in contact with the corium, while their apices, which as round openings or pores when viewed from the surface, emerge

Fig. 493.

.— TWO TASTE-BUDS THE PAPILLA FOLIATA E RABBIT. 450 DIA-AS (Engelmann).



en the ordinary lium-cells. The are flattened d the taste-buds, ing them in a sort t. The taste-buds elves may be des- d as consisting of ical and a central

The cells composing the cortical part are long and flattened with ng ends (fig. 494 *c*), and are in contact by their edges, extending base to apex of the organ (fig. 493); they are disposed in more than yer, and enclose the central part like the external scales of a leaf-bud. nclosed or central cells (fig. 494 *a*) are spindle-shaped, having an cement near the middle where the nucleus is situated, and being nged at each end by a process, one of which extends upwards ds the apex of the taste-bud, and is surmounted by a fine styliform nity which projects at the orifice, whilst the other, which is more r and sometimes branched near its extremity, passes down into the n of the mucous membrane, and is described as being connected a plexus of fine nervous fibrils found in this situation. The rity of these central *gustatory cells* to the "olfactory cells" of Max tze will be at once apparent.

The taste-buds were discovered by Lovèn and Schwalbe, independe other. They have now been found on the sides (but rarely on the up of the papillæ vallatæ of a great number of animals, and are seen a of the fungiform papillæ to be immediately described, as well as in mucous membrane apart from papillæ both on the posterior part and tongue, and also on the soft palate, on the epiglottis, and even withi aperture of the larynx. According to Krause the distribution of th follows that of the glosso-pharyngeal nerve. Their structure is n studied in the rabbit and hare, for in these animals there is found

Fig. 494.

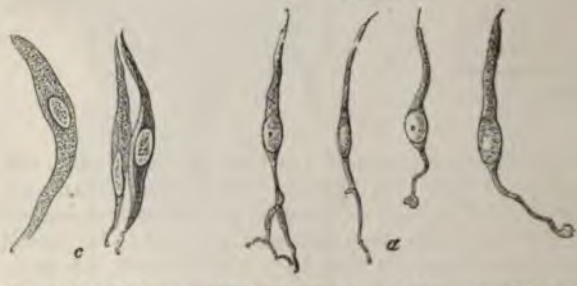


Fig. 494.—VARIOUS CELLS FROM TASTE-BUD OF RABBIT. 600 DIAMETERS (

a, Four cells from central part ; *b*, two cortical cells, and one central c tion ; *c*, three cells from cortical part.

of the base of the tongue an oval laminated structure, the so-called *pa* the laminæ composing which contain in the epithelium of their opp great numbers of those bodies. A small area, situated just in front of pillar of the fauces, of variable appearance, but usually with five folds, which are studded with taste-buds, exists in the human to regarded as representing a papilla foliata.

According to Engelmann, each taste-bud is composed of from 15 t

The taste organs of the amphibia have been longer recognised. T the form, not of buds but of patches interspersed here and there ordinary ciliated and columnar epithelium which covers the upper sides of the tongue.

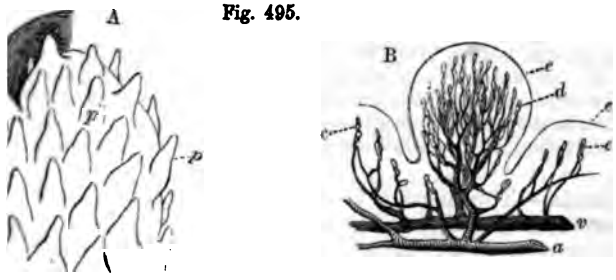
Flask-shaped bodies, resembling the taste-buds in structure, we described by Leydig as occurring in fishes. They are found both in th the mucous membrane of the mouth, and are believed to be gustato

The **fungiform papillæ**, more numerous than the last rounded eminences scattered over the middle and fore part of of the tongue (fig. 491, 3) ; but they are found in greater n closer together at the apex and near the borders. They ar tinguished in the living tongue owing to their deep red co are narrow at their point of attachment, but are gr larged towards their free extremities, which are blunt a (fig. 495).

The **conical papillæ** are the most numerous of all, as smallest. They are minute, conical, tapering, or cylindrical which are densely set over the greater part of the dorsum o (fig. 491, 4), but towards the base gradually disappear. arranged in lines diverging from the raphè, at first in an o

two ranges of papillæ vallatæ, but gradually becoming transls the tip of the tongue. At the sides they are longer and

Fig. 495.



RFACE AND SECTIONAL VIEW OF A FUNGIFORM PAPILLA (from Kölliker after Todd and Bowman).

ce of a fungiform papilla partially denuded of its epithelium (35 diameters); apillæ ; *e*, epithelium.

rm papilla with the blood-vessels injected. *a*, artery; *v*, vein; *c*, capillary le papillæ in the neighbourhood, covered by the epithelium ; *d*, capillary condary papillæ ; *e*, epithelium.

r, and arranged in parallel rows, perpendicular to the border le.

Fig. 496.

O FILIFORM PAPILLÆ, PITHELIUM, THE OTHER 35 DIAMETERS. (From er Todd and Bowman.)

stance of the papillæ eir upper extremities papillæ; *a*, artery, and ted by capillary loops; vering, laminated belæ, but extended into ocesses, *f*, over the læ.

dary papillæ which r some of the coniare peculiar both ng a number of es, giving them mess, and in the f their epithelial hich forms a sepaprocess over each papilla, greater in the papilla which g. 496, *e*, *f*). Over papillæ these proa pencil of fine own in the figure; name "filiform" een applied to these papillæ.

The papillary surface of the tongue is supplied abundantly with nerves, most of which terminate in end-bulbs, and a few in tactile corpuscles. In the fungiform papillæ the nerves are large and numerous; but they are still more abundant and of greater size, in the circumvallate papillæ, where they are chiefly distributed in the neighbourhood of the taste-buds (fig. 492).

The papillæ, besides being the parts chiefly concerned in the special sense of taste, also possess, in a very acute degree, tactile sensibility; and the conical and filiform papillæ, armed with their denser epithelial covering, serve a mechanical purpose, in the action of the tongue upon the food, as is well illustrated by the more developed form which these papillæ attain in many carnivorous animals.

Glands.—The mucous membrane of the tongue is provided with numerous small glands (*lingual glands*), collected principally about the posterior part of its upper surface, near the papillæ vallatæ and foramen cæcum, into which last the ducts of several open. These glands have usually been supposed to secrete mucus, but it has been ascertained that some of them, especially those which open in the trenches around the

Fig. 497.

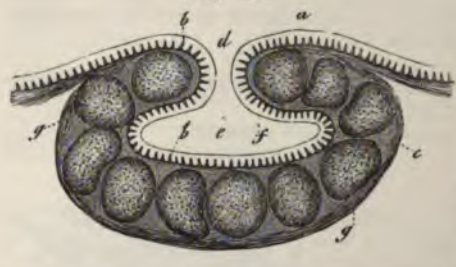


Fig. 497.—Section of a lymphoid crypt from the root of the tongue. 30 diameters. (Kölliker.)

a, epithelial lining; *b*, papilla of the mucous membrane; *c*, outer part of the crypt, formed of connective tissue; *d*, outlet, and *e*, cavity of the crypt; *g*, surrounding follicles.

papillæ vallatæ, and at other parts where taste-buds occur, yield a mucous watery secretion (Ebner). Other small glands are found also beneath the mucous membrane of the borders of the tongue. There is, in particular, a group on the under surface of the tongue on each side near the apex. They are there aggregated into a small oblong mass, out of which several ducts proceed and open in a line on the mucous membrane. Some of the glands are racemose; others acino-tubular.

The mucous membrane of the tongue, at least its posterior part, is largely composed of retiform or lymphoid tissue, which is collected at numerous points into the denser nodular masses known as follicular glands, or lymphoid follicles. The blood-vessels and lymphatics of this part of the membrane are numerous and large, but the papillæ on its surface are comparatively small, and are completely concealed by the thick superjacent epithelium. Here and there the mucous membrane exhibits recesses or crypts (fig. 497), either simple or surrounded by smaller ones which open into them. The walls of these recesses are generally studded with lymphoid nodules; and they receive many of the ducts of the mucous glands.

Muscular Substance.—The substance of the tongue is chiefly composed of muscular fibres running in various directions. Many belong to muscles which enter at its base and under surface, and attach it to other parts: these are called the *extrinsic muscles* of the tongue (hyo-glossus, chondro-glossus, genio-glossus, palato-glossus, stylo-glossus), and are elsewhere described. Others which constitute the *intrinsic* or *proper*

es, and are placed entirely within the substance of the organ, will re more particularly noticed. They are as follows :—

e **superficial lingual muscle** consists mainly of longitudinal , placed near the upper surface of the tongue, immediately beneath nucous membrane, and is traceable from the apex of the organ wards to the hyoid bone (figs. 498, 499, *l s*). The individual fibres ot run the whole of this distance, but are attached at intervals to ubmucous and glandular tissues. The entire layer becomes thinner rds the base of the tongue, near which it is overlapped at the sides thin plane of oblique or nearly transverse fibres derived from the o-glossus and hyo-glossus muscles.

he **inferior lingual muscle** consists of a rounded muscular band, nding along the under surface of the tongue from base to apex, and outside the genio-glossus, between that muscle and the hyo-glossus 499, *l i*). Posteriorly, some of its fibres are lost in the substance of tongue, and others reach the hyoid bone. In front, having first joined, at the anterior border of the hyo-glossus muscle, by fibres the stylo-glossus, it is prolonged beneath the border of the tongue r as its point.

he **transverse** muscular fibres of the tongue (figs. 498, 499, *t r*) together with the intermixed fat a considerable part of its sub- ce. They are found in the interval between the upper and lower itudinal muscles, and they are interwoven extensively with the other cular fibres. Passing outwards from the median plane, where they origin from a fibrous septum, they reach the dorsum and borders of tongue. In proceeding outwards, they separate, and the superior es incline upwards, forming a series of curves with the concavity

Fig. 498.

498.—LONGITUDINAL VERTICAL SECTION OF THE TONGUE, LIP, &c. (from Kölliker and Arnold).

symphysis of the lower jaw; *d*, incisor tooth; *h*, hyoid bone; *g h*, genio-hyoid le; *q*, genio-hyo-glossus spreading along the whole of the tongue; *t r*, transverse le; *l s*, superior longitudinal muscle; *g l*, lingual glands; *f*, lymphoid crypts; *e*, ttis; *l*, section of the lip and labial glands; *o*, cut fibres of the orbicularis oris; *l m*, or menti.

upwards. The fibres of the palato-glossus muscle are stated by Luschka and Henle to be continuous with fibres of the transverse set.

Vertical fibres (external perpendicular muscle of Zaglas), decussating with the transverse fibres and the insertions of the genio-glossus (fig. 499, *h'*), form a set of curves in each half of the tongue with their concavity outwards, and extending down and out from the dorsum to the under surface of the border, so that those which are uppermost are shortest.

Fig. 499.

Fig. 499. — TRANSVERSE VERTICAL SECTION OF THE TONGUE IN FRONT OF THE PAPILLÆ VALLATÆ, SEEN FROM BEFORE (from Kölliker).

g, the genio-hyo-glossal muscles; *g'*, the vertical fibres of the right side turned upwards to the surface; *l*, inferior longitudinal muscle with the divided ranine artery; *t r*, transverse muscle entire on one side, but partially removed on the other where the other muscles pass through it; *s*, septum linguæ; *h*, hyo-glossus; *h'*, its fibres spreading upwards almost vertically outside the genio-hyo-glossus; *h'*, vertical fibres reaching the surface; *l s*, divided plates of the fibres of the superior longitudinal muscle between the vertical fibres; *s t. g l*, stylo-glossus; *d*, glands near the border of the tongue.

Examined in transverse sections, the muscular fibres are seen to be arranged so as to render the substance divisible into an outer part or *cortex* and an internal or medullary part. The fibres of the cortex are principally longitudinal, derived superiorly from the lingualis superior, further outwards from the hyo-glossus, on the side from the stylo-glossus, and beneath this from the lingualis inferior. They ensheath the medullary part on all sides except inferiorly, where the genio-glossi muscles enter it between the inferior linguales. In the medullary part are found, imbedded in fat, the decussating fibres of the transverse muscle passing across, the genio-glossi radiating upwards and outwards, and the vertical muscle arching downwards and outwards. In addition to the movements which may be given to the tongue by the extrinsic muscles, this organ is capable of being curved upwards, downwards, or laterally by its cortical fibres, it is flattened by the vertical fibres, and its margins are again drawn together by the transverse, whilst the two last mentioned, acting together, would tend to lengthen the organ.

The septum of the tongue is a thin fibrous partition which extends forwards from the hyoid bone to the tip, and divides one half of the medullary part of the tongue from the other, but does not penetrate into the cortex.

The **arteries** of the tongue are derived from the lingual, with some small branches from the facial and ascending pharyngeal. The veins empty their contents into the internal jugular trunk.

The **nerves** of the tongue (exclusive of branches from the sympathetic nerves) are three; viz., the *lingual* or *gustatory* branch of the *fifth* pair, which supplies the papillæ and mucous membrane of the fore part and sides of the tongue to the extent of about two-thirds of its surface; the lingual branch of the *glosso-pharyngeal*, which sends filaments to the mucous membrane at the base of the tongue, and especially to the papillæ vallatæ; and lastly, the *hypoglossal* nerve, which is distributed to the muscles. Microscopic ganglia exist upon the expansions of the glosso-pharyngeal nerve, especially in the neighbourhood of the

læ vallatæ and papillæ foliatæ, and in the sheep and calf upon the gustatory ion of the fifth.

e chief lymphatic trunks accompany the ranine vessels, and after traversing or two small lymphatic glands, seated on the hyoglossus muscle, pass into eep cervical glands.

e detailed description of the blood-vessels and nerves will be found in the volume.

ecent Literature (especially relating to the papillæ and taste-buds).—*Lovén*, in f. mikr. Anat., IV., 1867 ; *Schwalbe*, in the same, and in Med. Centralbl., 1868 ; yss, in Med. Centralbl., 1869, and in Arch. f. mikr. Anat., VI ; *Krause*, in Göt- Nachr., 1870 ; *Hönigsschmied*, in Zeitschr. f. wiss. Zool., XXIII., 1871, and XXIX., and Med. Centralbl., 1872 ; *v. Aytai*, in Arch. f. mikr. Anat., VIII. ; *Engel-*, Article in Stricker's Handbook ; *Ditlevsen*, Abstr. in Hofmann and Schwalbe's b., 1872 ; *v. Ebner*, "Die acinösen Drüsen der Zunge, &c.," Gratz., 1873 ; *H.* ey (glands of tongue,) in Proc. Roy. Soc. 1874 ; *Sertoli*, in Moleschott's Unters. XI., ; *A. Hoffmann*, in Virchow's Arch., 1875 ; *Vintschgau*, Article "Geschmacksinn" ermann's Handbuch, 1880.

THE PALATE.

he roof of the mouth is formed by the palate, which consists of two ions ; the fore part being named the hard palate, and the back part, soft palate.

he osseous framework of the **hard palate**, already described with bones of the face, is covered by the periosteum, and by the lining mbrane of the mouth, which are firmly connected. The mucous mbrane, which is continuous with that of the gums, is thick, dense, ner pale, and much corrugated, especially in front and at the sides ; but moother, thinner, and of a deeper colour behind. Along the middle is a ridge or raphè ending in front in a small eminence, which corres- ds with the lower opening of the anterior palatine canal, and receives terminal filaments of the naso-palatine and anterior palatine nerves.

he hard palate is provided with many small glands (*palatine glands*), which a continuous layer between the mucous membrane and the periosteum ; and, the rest of the mouth, it is covered with a squamous stratified epithelium. corrugations of the hard palate are much better marked and more regular the fœtus (compare Gegenbaur, Die Gaumenfalten des Menschen, Morph. rb. iv., 1879).

n the rabbit fine nervous fibrils have been traced forming a plexus in the thelium (Elin).

The **soft palate** (velum pendulum palati) is formed of a duplicature mucous membrane inclosing muscular fibres and numerous glands. It nstitutes an incomplete and moveable partition between the mouth and e pharynx, continued from the posterior border of the hard palate, liquely downwards and backwards. Its form and its inferior con- ctions, bounding the isthmus of the fauces, have been already described, gether with the muscles which enter into its composition (Vol. I.).

The anterior or under surface of the velum, which is visible in the outh, is concave. The mucous membrane, continuous with that of the rd palate, is thinner and redder : it is covered with a similar epithe- um. The median ridge or raphè, which is continued backwards from e hard palate to the base of the uvula, indicates the original separation the palate into two lateral halves.

The posterior surface of the soft palate, slightly convex or arched, is ntinuous above with the floor of the nasal fossæ. It is slightly vated along the middle line, opposite to the uvula. The lower portion

The **tonsils** (tonsillæ, amygdalæ) are two prominen
occupy the recesses formed, one on each side of the fauc
anterior and posterior palatine arches (fig. 509, 23).

They are usually about half an inch in length, and a
and thickness; but they vary much in size in different i

The free inner surface of the tonsil, projecting into the
the palatine arches, has from twelve to fifteen orifices, whi
forated appearance. These orifices lead into recesses or c
stance of the tonsil, like those already described as occur
part of the upper surface of the tongue (fig. 497). T
tain a large number of lymphoid follicles ranged arou
these crypts, and between these is a quantity of less
tissue. The outer side of the tonsil is connected
surface of the superior constrictor of the pharynx, and
near to the internal carotid artery. Considered in
surface of the neck, the tonsil corresponds to the angle o
where it may be felt beneath the skin when it is enlarged

These structures receive a very large supply of blood from
viz., from the tonsillar and palatine branches of the facial art
descending palatine, the ascending pharyngeal and the dors
tongue. From these arteries fine branches and capillaries
abundantly to the lymphoid tissue and follicles and to the papil
membrane which lines the recesses. The veins are numerou
tonsillar plexus on its outer side. The nerves come from the
nerve, and from the fifth pair. Lymphatics are abundant, a
follicles with a close plexus; they eventually pass into th
cervical lymphatic glands.

THE SALIVARY GLANDS.

The saliva, which is poured into the mouth, and there
food during mastication, is secreted by three pairs of glan
their respective situations, *parotid*, *submaxillary*, and *sub*
ing in their general physical characters and minute structu

rior border, which lies over the ramus of the lower jaw, is less dis-
ly defined, and stretches forwards to a variable extent on the mas-
muscle. It is from this anterior border of the gland that the excre-
duct passes off; and there is frequently found in connection with
duct, and lying upon the masseter muscle, a small process or a sepa-
portion of the gland (*p'*), which is called *glandula socia parotidis*.
rying to raise the deeper part of the parotid gland from its position,
found to extend far inwards, between the mastoid process and the
as of the jaw, towards the base of the skull, and to be intimately con-
ed with several deep-seated parts. Thus, above, it reaches into and

Fig. 500.

. 500.—SKETCH OF A SUPERFICIAL DISSECTION OF THE FACE, SHOWING THE POSITION OF THE PAROTID AND SUBMAXILLARY GLANDS (Allen Thomson). $\frac{2}{3}$

, parotid gland ; *p'*, socia parotidis ; *d*, the duct of Stenson before it perforates the cinator muscle ; *a*, transverse facial artery ; *n*, *n*, branches of the facial nerve emerging n below the gland ; *f*, the facial artery passing out of a groove in the sub-maxillary d and ascending on the face ; *s m*, superficial portion of the submaxillary gland.

upies the posterior part of the glenoid cavity; behind and below, it
ches the digastric muscle, and rests on the styloid process and styloid
scles; and, in front, under cover of the ramus of the jaw, it advances
ertain distance between the external and internal pterygoid muscles.
The internal carotid artery and internal jugular vein are close to the
p surface of the gland. The external carotid artery, accompanied by
temporo-maxillary vein, passes through the parotid gland, and in
t situation divides into the temporal and internal maxillary arteries,
former soon giving off its auricular and transverse facial branches.

buccinator muscle; and then, after running for a short
forwards beneath the mucous membrane, opens upon th
the cheek, by a small orifice on a papilla opposite t
second molar tooth of the upper jaw. Its direction ac
be indicated by a line drawn from the lower margin of
ear to a point midway between the red margin of the lip a
nose. The length of the Stenonian duct is about t
half, and its diameter rather less than $\frac{1}{8}$th of an inc
where it perforates the buccinator, its canal is as l
quill, but at its orifice it is smaller than in any oth
only admit a fine probe.

The vessels of the parotid gland enter and leave it at num
arteries are derived directly from the external carotid, and
branches which pass through or near the gland. The veins
lymphatics join the deep and superficial set in the neck; and
or more lymphatic glands embedded in the substance of the p
come from the sympathetic plexus on the external carotid art
the facial, the auriculo-temporal and great auricular nerves.
it has been experimentally shown that the parotid derives
nerve-supply from the glosso-pharyngeal, through the lesser
nerve and the otic ganglion, the fibres finally passing to the
of the auriculo-temporal.

An instance is recorded by Gruber of a remarkable displace
on one side; the whole gland being situated on the masseter m
an enlarged socia parotidis (Virchow's Archiv, xxxii.).

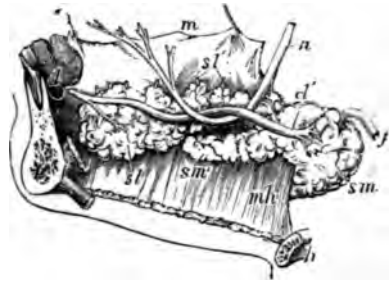
The submaxillary gland.—The submaxillary glan
sm), the next in size to the parotid, is of a spheroidal
about 2 or $2\frac{1}{2}$ drachms. It is situated immediately be
the inner surface of the inferior maxilla, and above the
In this position it is covered by the skin, fascia and pl
and its inner surface rests on the mylo-hyoid, hyo-gl
glossus muscles; above, it corresponds with a depressi
surface of the jaw bone; and it is separated behind

summit of a soft papilla (*d*) seen beneath the tongue. The obvious
re of this gland is like that of the parotid; but its lobes are larger,
rounding areolar web is finer, and its attachments are not so firm.
ver, its duct has much thinner coats than the parotid duct.

lood-vessels of the submaxillary gland are branches of the facial and
arteries and veins. The nerves include those derived from the sub-
y ganglion, and through this from the chorda tympani, from the lingual
of the inferior maxillary (and in rare cases from the mylo-hyoid branch of
ior dental nerve), and from the sympathetic.

sublingual gland.—The sublingual gland (fig. 501), the
of the salivary glands, is of a narrow oblong shape and weighs
one drachm. It is situated along the floor of the mouth, where
a ridge between the tongue and the gums of the lower jaw,
only by the mucous membrane. It reaches from the frænum

Fig. 501.



501.—VIEW OF THE RIGHT SUB-
LARY AND SUBLINGUAL GLANDS
THE INSIDE (Allen Thomson).

of the right side of the jaw,
from the left at the symphysis,
; the tongue and its muscles
en removed; and the mucous
e of the right side has been
off and hooked upwards so as to
the sublingual glands; *s m*, the
perficial part of the submaxillary
f, the facial artery passing
it; *s m'*, deep portion prolonged
inner side of the mylo-hyoid
m h; *s l*, is placed below the
large part of the sublingual
with the duct of Bartholin partly
; *s l'*, placed above the hinder small end of the gland, indicates one or two of the
perforating the mucous membrane; *d*, the papilla, at which the duct of Wharton
in front behind the incisor teeth; *d'*, the commencement of the duct; *h*, the hyoid
n, the gustatory nerve; close to it is the submaxillary ganglion.

e, in front, where it is in contact with the gland of the opposite
obliquely backwards and outwards for rather more than an inch and
. On its inner side it rests on the genio-hyo-glossus; below, it
ported by the mylo-hyoid muscle (*mh*), which is interposed between
the main part of the submaxillary gland; and it is here in close
ct with the Whartonian duct, with the accompanying deep portion
e last-named gland, and also with the lingual branch of the fifth
.

e lobules of the sublingual gland are not so closely united together
se of the other salivary glands, and the ducts from many of them
separately into the mouth, along the ridge which indicates the
ion of the gland. These ducts, named **ducts of Rivini,** are from
to twenty in number. Some of them open into the duct of
rton. One, longer than the rest (which is occasionally derived
rt also from the submaxillary gland), runs along the Whartonian
, and opens either with it or very near it; this has been named
duct of Bartholin.

The blood-vessels of this gland are supplied by the sublingual and su arteries and veins. The nerves are numerous, and are derived from the branch of the fifth.

STRUCTURE OF THE SALIVARY GLANDS.

These glands are constructed on the compound racemose type. ducts (traced backwards), after branching a certain number of terminate in fine ramuscules, into which the alveoli open. The al the salivary glands do not always present the form usually regar typical of the alveoli of a compound racemose gland. They are times dilatations of the extremities of the duct beset with saccul largements, sometimes more tubular and even somewhat con

Fig. 502.

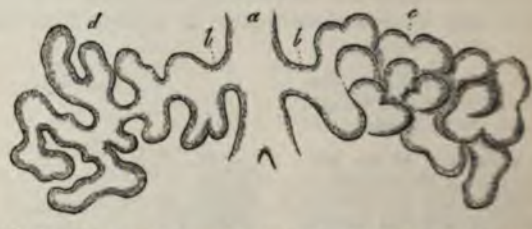


Fig. 502.—DIAGRAM OF THE CONSTRUCTION OF A LOBULE OF A TUBULO-AL (ACINO-TUBULAR) MUCOUS GLAND (from Kölliker).

a, duct; *b*, a branch of the duct; *c*, alveoli as they lie together in the gland; same separated, showing their connection as an irregular tube.

without marked sacculation (fig. 502) (acino-tubular variety), but th no essential difference between the two forms, transitions being met between them. The alveoli are enclosed by a basement membrane, is not complete as in many glands, but forms a basket-like investm the alveolus, the flattened cells which form it, being ramified and t together by their branches (fig. 503). There is however in addit delicate homogeneous substance occupying the meshes between the (see the left-hand alveolus in fig. 503). The cells of the basement brane are said to send inwards processes to form a sustentacular net amongst the alveolar cells.

Fig. 503.

Fig. 503.—MEMBRANA PROPRIA OF ALVEOLI ISOLATED (Heidenhain after dovsky).

The preparation is taken from the gland of the dog, which is similar in str to a mucous salivary gland.

The alveoli are united by the lo vessels and a small amount of loose nective tissue into lobules, and again by a larger quantity of the tissue into larger lobules. A considerable amount of connective t also accompanies the blood-vessels and duct in their ramifications thr the gland. The connective tissue, where it is in larger amoun lamellar in character (Klein), and it contains, besides the ordi

ned cells, a certain number of granular plasma-cells and lymph-
uscles, with fat cells occasionally.

e alveoli of the salivary glands may be divided into two classes,
ding to the nature of their secretion :—those of the one kind yield-
a ropy secretion characterised by containing mucin, and those of
other kind, a thinner more watery secretion, sometimes containing
nsiderable amount of serum-albumin, so that the secretion
ulates on being heated. The two kinds of alveoli may accordingly
istinguished as *mucous* and *serous* or *albuminous*, (Heidenhain); they
r from one another both in appearance and in the nature of their
ting cells. In some cases an alveolus may contain mucous and serous
side by side.

Fig. 504.

504.—SECTION OF PART OF
E HUMAN SUBMAXILLARY
AND (Heidenhain).

the right of the figure is a
of mucous alveoli, to the
group of serous alveoli.

e human parotid and that
ll mammals is composed
erous alveoli, and the sub-
nal gland of mucous alveoli,
in man the submaxillary is
ixed gland, containing both
ls of alveoli, although the
us are the more numerous
504). In the dog and most
r animals it is purely a
ous gland, and in the rabbit
guinea pig it is purely a
us gland. Similar differ-
es have already been noticed
570) in the small glands of
tongue. In the guinea pig
e are small flat mucous glands of tubular structure connected both to the
tid and submaxillary, one to each, and sending their ducts to open into the
s of those glands (Klein).

Mucous alveoli.—In the mucous glands and mucous alveoli of mixed
ds most of the alveolar cells, when the gland is in the inactive con-
n, appear large, clear, and almost spheroidal in shape, and nearly
he alveoli, which are distended by the cells (right-hand side of fig.
). The nucleus of each cell is in the part of the cell next to the
ment membrane, against which it is generally flattened, and the cells
cause the basement membrane to be bulged out opposite to them.
reparations hardened in alcohol, the cells are finely granular, and
the exception of the part around the nucleus are scarcely stained
armine (fig. 505, A).

When isolated, they not unfrequently exhibit processes, one from the
of each cell : the projection is flattened and overlaps the base of a
hbouring cell (Kölliker). The peculiar clear appearance of these
is due to the accumulation within them of mucin (or of a sub-
ce "mucigen" from which mucin is formed) ; this substance is pre-
tated by acids, but swollen up, and the cells are destroyed, by the
on of water or alkalies.

Besides the "mucin cells" there are met with in most alveoli of glands, cells of a different character, which from their position named "marginal cells." In some mucous glands, *e.g.*, the submaxil the cat, they form an almost complete outer layer, next to the ba membrane, and enclosing the mucin-cells, but in the dog's subma gland they occur only in small semilunar masses (lunulæ of Gi flattened up between the basement membrane and the mucin-cel 505, A; fig. 507, *s*). These marginal-cells are small and granula stain deeply with carmine.

Fig. 505.

Fig. 505.—Sections of the orbital gland of the dog. A, during rest. I a period of activity (Heidenhain after Lavdovsky).

In A, the cells of the alveoli are large and clear, being filled with the ma secretion (in this case, mucigen) which obscures their protoplasm, but some of have not participated in the formation of the secretion, and these remain s protoplasmic, forming the crescentic group seen in most of the alveoli.

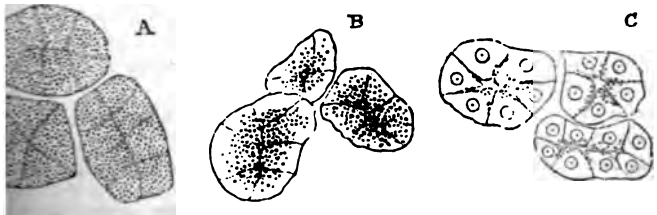
In B, the accumulated material is discharged from the cells, which appear disintegrated in consequence. Both the cells and the alveoli are much smaller, protoplasm of all the cells is now apparent.

If the mucous glands are stimulated to secretion, the mucin-cells gradually smaller and less clear, their contents being exuded in the f mucus, which first fills the cavity of the alveolus and then passes on i duct. At the same time the cells are easily stained with carmine a nuclei are no longer flattened, but assume a more rounded form and position (fig. 505, B). If the gland be strongly urged to activity as by pr stimulation of its cerebral nerves, the mucin-cells may undergo still m found alterations, and may even become partially or wholly disintegra removed from the alveolus with the secretion. It is uncertain whet whole cell may thus be destroyed, or whether the part surrounding the may not remain and regenerate the cell; this is certainly the case in som small mucous glands of the mouth in which no marginal cells can be see probable however that in the salivary glands, some at least of the mucin-c entirely destroyed, and the marginal cells multiplying and becoming fill secretion, serve to replace those which are thus lost. In this way w suppose that, even while the discharge of secretion is still proceedin secreting cells are forming, at the same time that some of the older c being destroyed (Heidenhain).

Serous alveoli.—In the serous glands and serous alveoli of

he cells, in the inactive condition of the glands, are in the fresh conand in osmic preparations seen to be packed full of distinct granules, luminous nature, which obscure their nuclei. The granules are d in the protoplasm of the cells and the latter almost completely lveoli, scarcely any lumen being discernible (fig. 506, A).

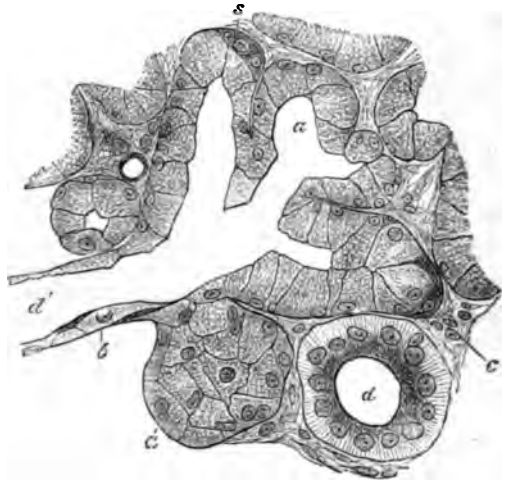
Fig. 506.



06.—ALVEOLI OF SEROUS GLANDS. A, AT REST. B, AFTER A SHORT PERIOD CTIVITY. C, AFTER A PROLONGED PERIOD OF ACTIVITY. (Langley.)

a short period of activity the granules are found to have disappeared in r part of the cell, the inner part being still distinctly granular and some being apparently free within the lumen of the alveolus, now becoming (fig. 506, B). With more prolonged activity (fig. 506, C) the clear rt increases in extent, and the granules are found only in the part of the ch is close to the lumen, and in those parts which are contiguous to the cells, (corresponding perhaps to fine capillary clefts which pass from the f the alveolus between the cells). The nuclei have now become distinct,

Fig. 507.



.—SECTION OF THE XILLARY GLAND OF DOG, SHOWING THE NCEMENT OF A DUCT IE ALVEOLI. MAG- 425 DIAMETERS. 8.).

of the alveoli, several are in the section grouped around the ement of the duct, d'; veolus, not opened by ; *b*, basement mem- section; *c*, interstitial ve tissue of the gland; a of a duct which has way from the alveoli, w lined with charac- ly-striated columnar semilunar group of ained cells at the y of an alveolus.

cells are smaller. We may suppose therefore that the granules, which no ontain the specific elements of the secretion, are formed by or from the sm of the cells during rest, and are discharged into the lumen and dissolved activity. Probably however even during activity new granules are conbeing formed and passed onwards towards the lumen. According to , the three *processes of growth* of the clear protoplasm, conversion of

this into granules, and discharge of these into the lumen, are all pro simultaneously in different parts of the cell during activity.

In glands which have been hardened in alcohol the granules are foun dissolved and their place occupied by a clear substance which does no with carmine.

Ducts.—In the serous glands, and serous parts of mixed glan first or *intercalary part of the duct* which conveys the secretion the alveoli is narrow, and lined with clear flattened cells with elo nuclei. After a longer or shorter course, this part passes by a what narrower "neck," lined with cubical cells with small nucl the intralobular ducts (Klein).

In the mucous glands the intercalary ducts are also lined (fig. 5 with clear cells continuous with the cells of the alveoli, but fla against the basement membrane so as to leave a considerable lume

This first part of the duct is generally shorter than the corresponding the serous glands, and is regarded by Klein as representing only the part termed the "neck;" more probably, however, it must be looked upon as senting both parts, although they are not here so clearly differentiate intercalary part of the ducts is described by Klein as being lined, with epithelium, by a special delicate nucleated membrane, which in some ani continued into the intralobular ducts.

In the next or *intralobular part of the duct* (fig. 507, *d*) the cha of the epithelium changes abruptly, the cells becoming large and coh or conical, the rounded or truncated apex being directed towar lumen of the tube. Each cell contains a spherical nucleus nea centre (fig. 508, *a*). The part of the cell next the lumen of th

Fig. 508.

Fig. 508.—STRIATED EPITHELIUM CELL, FROM THE SUBMAXILLARY SALIVARY GLAND; HIGHLY MAGNIFIED. SEMIDIAGRAMMATIC. (E.A.S.)

gr, granular protoplasm; *str*, striæ; *n*, nucleus.

is granular in character, whereas the part nearest basement membrane is finely striated longitudinally. This striated appearance is most distinct the ducts of the submaxillary gland; it is due to the presence of a like or fibrillar structure in that part of the cell.

The larger ducts acquire a coating of fibrous and elastic tissue co the basement membrane, and, except in those of the sublingual gla few plain muscular fibre-cells are also to be found. The columna thelium is here double, a second row consisting of somewhat s cells lying outside, and fitting between, the elongated cells whi continuous with those of the smaller ducts.

Vessels and nerves.—The blood-vessels of the salivary glands are num and form a close capillary network outside the basement membrane both alveoli and the ducts.

The lymphatics commence in the form of lacunar clefts between and the alveoli, lying closer to these than do the networks of blood-cap (Gianuzzi). The issuing lymphatics accompany the blood-vessels and duct

The nerves are large and numerous, and many of them exhibit minute g especially those in the dog's submaxillary. There are fewer in the human maxillary gland, and no ganglia in the parotid (Klein). Some of them hav

ued to terminate in Pacinian corpuscles of a simple kind (Krause), and many
ubt supply the blood-vessels. There are good reasons for believing that the
fibres come into intimate relation with the secreting cells of the glands, but
t manner such connection may occur is not known. According to Pflüger,
ement membrane of the alveoli, as well as of the ducts, is perforated by
rves, which lose their medullary sheath, and, breaking up into a number
nches, become connected with the cells. Other observers, however, have
to corroborate these statements.

Recent Literature of the salivary glands is comprised in the list of works given
the article "Secreting Glands." To these may be added a recent paper by Klein,
"Quarterly Journal for Microscopical Science," April, 1882.

THE PHARYNX.

e pharynx (fig. 509) extends from the base of the skull to the
r border of the cricoid cartilage, and forms a sac continued at the
r end into the gullet, with apertures in front, which lead into the
, mouth and larynx. The velum projects backwards into it, and
g the passage of the food is drawn backwards by muscular action
completely to separate an upper from a lower part. In all, seven
ings lead into the cavity of the pharynx; viz., above the velum,
two posterior openings of the nares (*choanæ narium*), and at the
the apertures of the Eustachian tubes (fig. 509, 10); while
w the velum, there is first the passage leading from the mouth;
the superior opening of the larynx, and lastly the passage into
esophagus.

he pharynx is about 4½ inches in length, and is considerably wider
s than from before backwards. Its widest part is opposite the
ua of the hyoid bone; below this it rapidly contracts like a funnel
ards its termination in the gullet, opposite the cricoid cartilage, where
narrowest.

he posterior wall of the pharynx at its upper end forms a cul-de-sac on each
opposite the tip of the petrous bone, and lies in a curve, with its convexity
ards, in front of the recti capitis antici muscles.

Attachments.—The walls of the pharynx are formed by a fascia or
r of fibrous tissue, named the pharyngeal aponeurosis, dense at its
er part but lax and weak below, which is covered by muscles and
d by mucous membrane. At its upper end this fibrous wall is attached
he posterior part of the body of the sphenoid bone, and passes out-
rds to the petrous portion of the temporal bone and on to the Eustachian
e. It is strengthened in the middle line by a strong band descending
ween the recti antici muscles from a part of the basilar process of the
ipital bone, which often presents a marked tubercle (*pharyngeal
ercle*, see vol. i.).

Behind, the pharynx is loosely connected by areolar tissue to the pre-
tebral fascia covering the bodies of the cervical vertebræ and the muscles
ich rest upon them. At the sides it has similar connections with the
loid process and its muscles, and with the sheaths of the large vessels
l nerves of the neck. In front, it is attached in succession to the sides
the posterior nares, the mouth and the larynx.

hus commencing above by a tendinous structure only, the pharynx is connected
means of muscle and fibrous *membrane*, first, with the internal pterygoid plate

then with the pterygo-maxillary ligament, and next with the mylo-hyoid
of the lower jaw; below this, it is attached to the sides of the tongue,
hyoid bone, and stylo-hyoid ligament; and, still lower down, to the thyro
cricoid cartilages.

Structure.—The *muscles* of the pharynx are the superior, middle
inferior constrictors, the stylo-pharyngeus, and the palato-pharyn
They have already been described in vol. i.

Fig. 509.

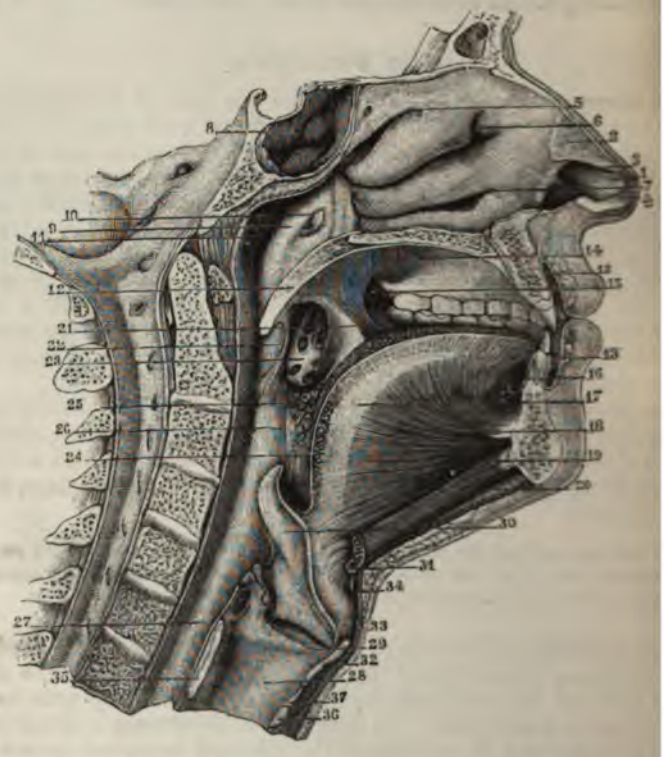


Fig. 509.—MEDIAN SECTION OF THE MOUTH AND PHARYNX (Sappey).

1 to 8, relate to parts in connection with the nostrils; 9, upper or respiratory
the pharynx; 10, aperture of the left Eustachian tube; 11, depression of the
membrane; 12, velum palati; 13, 13, vestibulum oris; 14, arch of the palat
space at the back of the dental series; 16, 17, tongue; 18, genio-glossus; 19,
hyoid; 20, mylo-hyoid, cut; 21, 22, anterior and posterior pillars of the fauc
tonsil; 24, posterior vertical part of the tongue; 25, its glandular eminences
pressions; 26, 27, lower part of the pharynx; 28 to 37, refer to parts of the
30, epiglottis.

The *mucous membrane* is continuous at the several apertures with
of the adjacent cavities. It varies somewhat in its character in dif
parts. Its upper portion, which presents numerous folds with inte
ing recesses, is thick where it adheres to the base of the skull, but

near the entrance of the Eustachian tubes and the posterior nares : situation numerous racemose mucous glands are found collected or beneath the mucous membrane. Lymphoid follicles also exist bout the whole of the pharynx.

portion of these, forming a glandular mass similar to that composing the stretches across the back of the pharyngeal cavity between the orifices of Eustachian tubes (Kölliker).

l-marked recess of the mucous membrane, known as the *bursa pharyngea*, s constant in the fœtus and young subject, is occasionally present in the the middle line posteriorly, extending as far upwards as the pharyngeal . It opens by a narrowed orifice below the glandular mass just mentioned. re *v. Teutleben*, Die Tubentonsille, in Zeitschr. f. Anat. u. Entw., 1876; *yhofner*, Ue. d. Tonsilla u. Bursa pharyngea, in Wiener Sitzungsb. II. 1878). (For the description of a remarkable case of lateral diverticu- the pharynx, see a paper by M. Watson in the Journal of Anat. and , 1874.)

he part opposite the fauces, the mucous membrane exactly resembles the mouth. Lower down it becomes paler, and at the back of the it forms several longitudinal folds. The epithelium upon the upper of the pharynx, nearly as low down as the base of the uvula, is ar and ciliated; but, below that point, it is scaly and stratified. fœtus the ciliated epithelium has a more extensive distribution, often persists in the recesses and gland ducts of all parts of the ix.

THE ŒSOPHAGUS.

œsophagus or **gullet,** the passage leading from the pharynx to mach, commences at the cricoid cartilage opposite the sixth cer- vertebra, and passing through the diaphragm opposite the tenth enth dorsal vertebræ, there ends by opening into the stomach.

length of the œsophagus is about 9 or 10 inches. It is of smaller ter than any other division of the alimentary canal, its narrowest eing at the commencement behind the cricoid cartilage; it is also y constricted in passing through the diaphragm, but, below that, s into the stomach. It is not quite straight in its direction, but ree slight curvatures. One of these is an antero-posterior flexure, ponding with that of the vertebral column in the neck and thorax. ther two are slight lateral curves; for the œsophagus, commencing median line, inclines to the left side as it descends to the root of the thence to the fifth dorsal vertebra it gradually resumes the mesial on; and finally, it deviates again to the left, at the same time g forward towards the œsophageal opening of the diaphragm.

nnections.—In the lower cervical and upper dorsal region the agus is applied to the anterior surface of the spine, being connected t and with the longus colli muscle by loose areolar tissue; between the bodies of the dorsal vertebræ the thoracic duct ascends obliquely right to left; in its lower third it is placed in front of the aorta. In ck, the œsophagus lies close behind the trachea, (projecting about ter of an inch to the left of that tube), and the recurrent laryngeal ascends on either side in the angle between them; on each side is mmon carotid artery, and also a part of the thyroid body, but, as ophagus inclines to the left side, it is in more immediate connection the left carotid. In the thorax, the œsophagus is successively

covered in front by the lower part of the trachea, by the commence… of the left bronchus, and by the pericardium. The aorta, except near … diaphragm, where the œsophagus is in front of the vessel, lies to the … and the vena azygos to the right and behind; the pneumogastric … descend in close contact with its sides, and form a plexus around it, … left nerve proceeding gradually to the front, and the right nerve … behind it. Lastly, the œsophagus, which is here placed in the … between the two pleuræ, comes partially in contact with both of … membranes but more extensively on the right side.

STRUCTURE OF THE ŒSOPHAGUS.

The walls of the gullet are composed of three coats; viz., an exter… or muscular, a middle or areolar, and an internal or mucous coat. … side the muscular coat there is a layer of areolar tissue, with well … elastic fibres.

The **muscular coat** consists of an *external longitudinal layer* (… section in fig. 510, *b*) and an *internal* circular layer (*c*). This … arrangement of the muscular fibres prevails throughout the whole … of the alimentary canal; but the two layers are here much thicker, … uniformly disposed, and more evident than in any other part, … quite at the lower end of the intestine. The external or *longitudi…* fibres are disposed at the commencement of the tube in three …

Fig. 510.

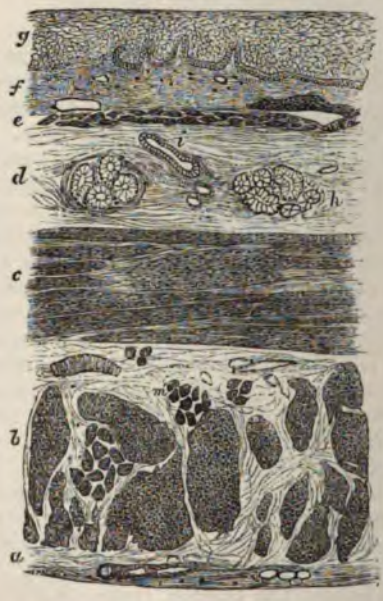


Fig. 510.—Section of the … œsophagus. (V. Horsley)

The section is transverse, and … near the middle of the gullet. … fibrous covering; *b*, divided … the longitudinal muscular … transverse muscular fibres; *d*, … mucous or areolar layer; *e*, … laris mucosæ; *f*, mucous … brane, with vessels and part of … lymphoid nodule; *g*, laminated … thelial lining; *h*, mucous gland; … gland duct; *m'*, striated … fibres cut across.

one in front, and one on each side. The lateral bands are continuous above with the inferior constrictor of the pharynx; the anterior arises from the back of the cricoid cartilage at the prominent ridge between the posterior crico-arytenoid muscles, and its fibres spreading out on each side of the gullet as they descend, soon blend with those of the lateral … to form a continuous … around the tube. The direction of many of the fibres is at first oblique, but towards the lower end it is more directly longi… The internal or *circular* fibres are separated above by the fibres … lateral longitudinal bands from those of the inferior constri… the pharynx. The rings which they form around the tube have

tion at its upper and lower part, but in the intervening space
oblique. At the lower end, both layers of fibres become
with those of the stomach.
ɔular coat of the upper end of the œsophagus is of a well-
colour, and consists wholly of striped muscular fibres; but
, where it becomes somewhat paler, these are gradually re-
lain muscular fibres, so that in the lower half of the tube the
most all of the involuntary kind. A few striped fibres, how-
ɐen found mixed with the others throughout its whole length,
y mammals the striped fibres preponderate throughout.

ıdinal fibres of the œsophagus are sometimes joined by a broad band of
le, passing from the left pleura, and sometimes also by another from
ıchus. According to Cunningham, the former is almost constantly
the latter very frequently.

ılar or **submucous** coat is placed between the muscular and
ıts, and connects them loosely together. It exceeds the
nbrane considerably in thickness, and in it are contained the
510, *h*), which open on the mucous membrane.
ous membrane is of firm texture, and is paler in colour than
pharynx or stomach. From its loose connections its outer
reely movable on the muscular tunic; and under ordinary
ɐs the mucous lining is thrown into longitudinal folds or
ı are in mutual contact. These folds disappear on distension

ɒapillæ (*f*) are seen upon the mucous membrane, and the
ɾered with a thick stratified scaly epithelium. In the embryo
period the œsophagus is lined by columnar ciliated epithelium
, patches of which may persist even to the time of birth

ll compound racemose or tubulo-racemose glands, named
glands, which are for the most part seated in the submucous
re especially numerous at the lower end of the tube. A few of
are situated in the substance of the mucous membrane. In
ls of these glands are columnar (Klein).
ıus membrane is bounded next to the submucous coat by longi-
sposed plain muscular fibres which, imperfect above, form a
layer towards the lower end of the tube (*muscularis mucosæ*, *e*).

f the œsophagus in part of its extent, without other abnormality,
ɪrded (Blaes, quoted by Meckel).
ıd nerves.—The *blood-vessels* of the œsophagus have for the most
udinal arrangement. There are separate networks for the mucous
he muscularis mucosæ and the muscular coat, and the glands and
which are met with in the submucosa have each their capillary
ɟphatics are found in both the submucous and mucous coats, those of
ımencing as in the mouth and pharynx within the papillæ. A small
ɾmphoid tissue is also present. Both here and in the pharynx the
ɜ mucous glands are invested by sinus-like lymphatic vessels (Kidd).
ɪrm a gangliated plexus between the two layers of the muscular coat,
ırts of the alimentary canal, but it is characterised by the compara-
ɯze of the groups of ganglion-cells and of the cells themselves, and
fact that it contains a large number of medullated nerve-fibres
n the pneumo-gastric nerves). Each of these fibres in passing a
ɑined by a non-*medullated fibre* derived from one of the cells of the

ganglion, a T shaped junction being formed, as in the case of the large p on the posterior roots of the spinal nerves. The medullated fibre then pa and after branching a certain number of times, is finally distributed in the m tissue in the striped fibres of which it terminates in the form of end-plate ordinary type (Ranvier). There is another nervous plexus in the sub tissue.

Recent Literature.—*Gillette*, in Journ. de l'anat., 1872 (tunique muscu *Mouton*, in Rev. d. sci. méd., 1874 (calibre); *Cunningham*, in Journ. of Anat. Phys., X., 1876; *Neumann*, in Arch. f. mikr. Anat., XII., 1876; *Klein*, in Qu micr. sci., XX., 1880; *Ranvier*, Leçons, 1880 (nerves and muscular coat).

THE ABDOMINAL VISCERA.

As that part of the digestive canal which is found beneath the phragm, and consists of the stomach and intestines, is situated w the cavity of the *abdomen*, and occupies, together with the liver, by the greater part of that cavity, the general topographic relations of abdominal viscera may here be briefly explained.

THE ABDOMEN.

The abdomen is the largest serous cavity in the body, and is by an extensive and complicated serous membrane, named the p *toneum*. It extends from the diaphragm above to the levatores muscles below, and is subdivided into two parts: an upper and l part, *the abdomen*, properly so called; and a lower or *pelvic* The limits between these portions of the cavity are marked by the of the true pelvis.

The enclosing walls of this cavity are formed principally of muscles a tendons which have been already described. They are strengthened interna by a layer of fibrous tissue lying between the muscles and the peritoneum, f different parts of which are described under the names of transversalis fasci iliac fascia, and anterior layer of the lumbar aponeurosis. These walls a pierced by several apertures, through which are transmitted the great vessels an some other parts, such as the several diaphragmatic apertures for the aorta, ve cava and œsophagus, and the femoral arches and inguinal canals. In the media fibrous substance of the anterior wall lies the umbilical cicatrix. The cavity o the pelvis is also lined with strong fasciæ, and partially by peritoneum, and at th lower part are the apertures for the transmission of the rectum and the genito urinary passages.

For the purpose of enabling reference to be made to the situation and condi tion of the contained organs, the *abdomen proper* has been artificially subdivided into certain regions, the boundaries of which are indicated by lines drawn upon the surface of the body. The description of these regions, together with an enumeration of their contents, has been given at the end of the first volume.

The surfaces of the viscera which are in contact one with another and with the wall of the cavity, are rendered glistening by a coating derived from the lining serous membrane of the cavity.

THE PERITONEUM.

The **peritoneum**, or serous membrane of the abdominal cavity, is by far the most extensive and complicated of the serous membranes. Like the others it may be considered to form a shut sac, but in the female, the two Fallopian tubes open at their free extremities into its cavity. The *parietal* layer is connected with the fascia lining the abdomen and pelvis

ns of areolar tissue (subperitoneal); it is more firmly adherent along dle line of the body in front, as well as to the under surface of phragm. The *visceral* layer, which is thinner than the other, a more or less complete covering to most of the abdominal and organs.

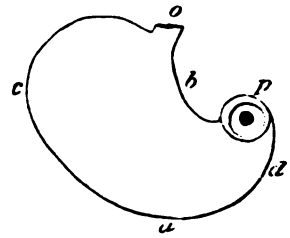
folds of the peritoneum are of various kinds. Some of them, constituting *nteries*, connect certain portions of the intestinal canal with the posterior the abdomen; they are, the mesentery properly so called for the jejunum um, the meso-cæcum, transverse and sigmoid meso-colon, and the meso-. Other duplicatures exist, which are called *omenta;* they are the great m or epiloön, the small omentum, and the gastro-splenic omentum. Lastly, reflexions of the peritoneum from the walls of the abdomen or pelvis to which are not portions of the intestinal canal, are named *ligaments:* such ligaments of the liver, spleen, uterus, and bladder.
further account of the peritoneum will be deferred until the abdominal have been described.

THE STOMACH.

e stomach is seated in the left hypochondriac and the epigastric . It lies in part against the anterior wall of the abdomen, and beneath the liver and diaphragm, and above the transverse colon. g axis, which is curved, is not horizontal in position, but lies ob-, being considerably higher on the left side than on the right.
shape it is somewhat conical or pyriform (fig. 511). The left ity is the larger, and is named the *cardiac* end. The right or end is named the *pyloric* extremity (*p*). Of its two orifices, the one ich food enters from the œsophagus is named the *cardiac* orifice (*o*), ther, by which it passes into the duodenum, and which is placed on er level, and more forwards, is the *pyloric* orific.

511.—Diagrammatic outline of the stomach as seen from behind (His). ¼

Fig. 511.



reat curvature; *b*, lesser curvature; *c*, left reat cul-de-sac, or fundus; *d*, small cul-de- antrum pylori; *o*, œsophageal orifice or ; *p*, pyloric extremity.

he cardiac orifice is two or three es from the larger extremity, which ects upwards and to the left of the ing, forming the great *cul-de-sac* or s (*c*).
etween the cardiac and the pyloric orifices, the outline of the stomach rved along its upper and lower borders. The upper border, which also to the right, about three or four inches in length, is concave, forms the *lesser* curvature (*b*); while the lower border, which is h longer, and, except towards the pylorus, convex, forms the *greater* ature (*a*).
owards the pylorus, the small end of the stomach describes a double d, opposite to the first turn of which is a prominence or bulging, etimes named the *small cul-de-sac* or *antrum pylori* (*d*).

here is sometimes a distinct constriction near the pyloric end of the stomach, rfectly separating it into *two parts*. This condition may be in great

Dimensions.—These vary greatly in different subject
according to the state of distension of the organ. When
filled, its length is about 10 or 12 inches ; and its diameter
part, from 4 to 5 inches. It weighs, when freed from other
4½ ounces in the male, and somewhat less in the female (C
The wall of the stomach is thinner than that of the œsophagus
than that of the intestines generally. It is thickest at the p

Connections.—The borders of the stomach are connecte
of peritoneum in their whole extent. Thus, the superi
connected with the under surface of the liver by a duplicat
toneum, the gastro-hepatic or lesser omentum, and at the
cardia, between the œsophagus and the diaphragm, is a small
the gastro-phrenic ligament ; to the inferior border is attach
omentum, beneath which is the transverse arch of the colon,
left extremity it is connected with the spleen by a duplicatu
neum, continuous with the left border of the great omentum, an
gastro-splenic omentum or ligament. The blood-vessels and
of the stomach pass within these duplicatures of the membran
the organ along its two curvatures. Its anterior and poster
are free, smooth, and covered with peritoneum. The ante
which is directed upwards as well as forwards, is in contact
the diaphragm and the under surface of the liver, and lowe
the abdominal parietes opposite the epigastric region, whi
named the *pit of the stomach*. The posterior surface is turned
and backwards, and rests upon the transverse meso-colon, b
are the pancreas, spleen, left kidney and supra-renal body, a
vessels of the abdomen.

At its cardiac orifice it is continuous with the gullet,
fixed by reflection of the peritoneum to the œsophageal ope
diaphragm. The pyloric extremity, situated lower down, n
surface, and having greater freedom of motion, is continu
duodenum, is covered by the concave surface of the liver,
cases touches the neck of the gall-bladder.

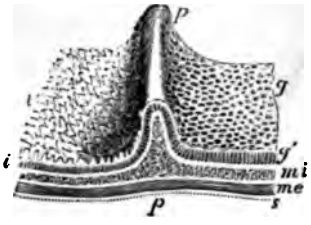
STRUCTURE OF THE STOMACH.

The stomach has four coats named in order from with

: **second** or **muscular coat,** is composed of plain muscular tissue, ıg three sets of fibres, disposed in layers, and named, from their ion, the longitudinal, the circular, and the oblique fibres.

› **first** or outermost layer consists of the *longitudinal* fibres (fig. ıe, fig. 513, A), which are in direct continuity with those of the ıagus. They spread out in a radiating manner from the cardiac

Fig. 512.



2.—Diagrammatic view in perspective portion of the coats of the stomach duodenum, including the pylorus m Thomson).

he inner surface of the gastric mucous me ; *g'*, section of the mucous membrane e pyloric gastric glands ; *v*, the villous sur- the mucous membrane of the duodenum : m of the same with the intestinal glands ts of Lieberkühn ; *p p*, the ridge of the ring, with a section of its component ns *i*, deep or circular layer of muscular these are seen in the section to form the sphincter : *m e*, external or longitudinal f muscular fibres ; *s*, the serous covering.

ı, and are found in greatest abundance along the curvatures, espe- the lesser one. On the anterior and posterior surfaces they are thinly scattered, or scarcely to be found, but towards the pylorus rell marked and form a thick uniform layer, which, passing over pylorus, becomes continuous with the longitudinal fibres of the ınum.

ıe second set consists of the *circular* fibres (fig. 512, *mi*, fig. 513, B) h form a complete layer over the whole extent of the stomach. commence by small and thinly scattered rings at the left extremity e great cul-de-sac, describe larger and larger circles as they sur- l the body of the stomach concentric to its curved axis, and rds the pyloric end again form smaller rings, and at the same time me much thicker and stronger than at any other point. At the rus itself they are gathered into an annular bundle (fig. 512 in on), which projects inwards into the cavity, and forms, within nnular fold of mucous membrane, the pyloric sphincter. Some of ircular fibres appear to be continued from those of the œsophagus, ding from its right side.

he innermost muscular layer is incomplete, and consists of the ue fibres (fig. 513, C). These are continuous with the circular fibres ıe gullet, on the left of the cardiac orifice, where they form a con- able stratum ; from that place they descend obliquely upon the an- r and posterior surfaces of the stomach, where they spread out from another, and taking the direction of the circular fibres gradually pear on the greater curvature.

ıe **submucous coat** of the stomach is a distinct layer connecting nuscular and mucous coats (fig. 512, between *mi* and *g*). It consists eolar tissue, in which occasional fat-cells may be found ; and it is eat of division and passage of the blood-vessels.

ıe **internal coat** or **mucous membrane** is a smooth, soft, rather : and pulpy membrane, which in the fresh state has generally a what pink hue owing to the blood in its capillary vessels. In ıcy the vascular redness is more marked.

The mucous membrane is thickest in the pyloric region, and
in the great cul-de-sac. It always becomes thinner in old age.

Fig. 513.

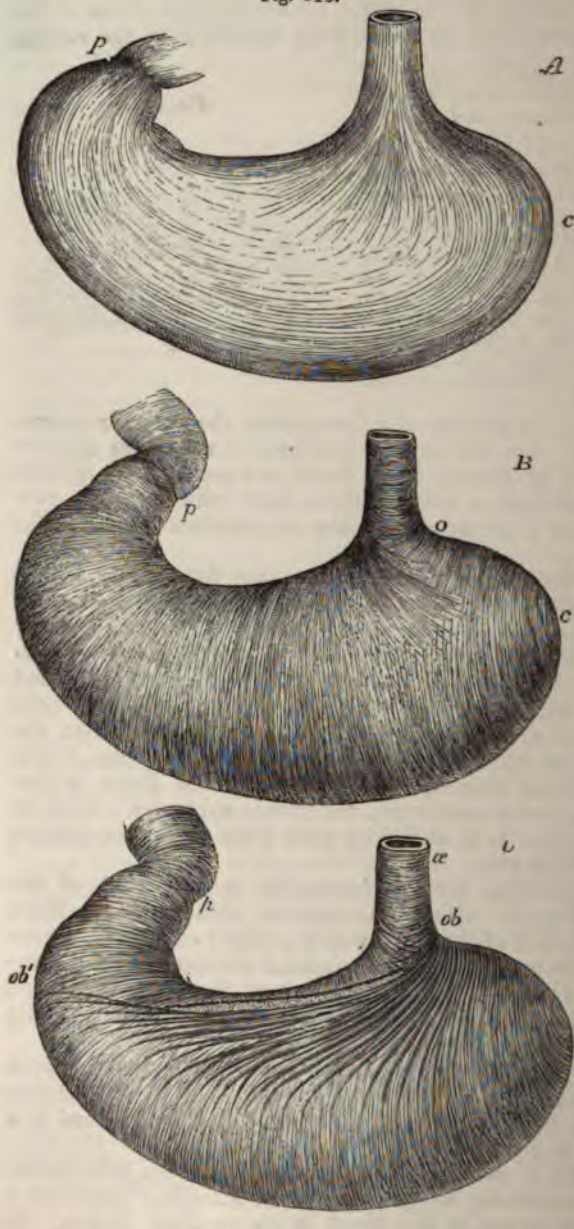


Fig. 513.—
OF THE
MENT
FIBRES
MUSCULA
THE
(Allen T
½

A, exter
of longitu
bres, as s
the outsi
middle lay
cular fibres
on remov
longitudinal
C, oblique
posed by
some of the
the circular
cut edges
are seen b
lesser curva
c, the card
p, the pylor
in A, are sh
stronger lon
fibres passi
the lesser an
curvatures,
round the
end, and th
ating fibres
from the en
gullet over th
(and back)
stomach; in
nearly unifor
of circular f
two sets cross
other very o
at o, and at
diac end b
concentric
centre of th
cul-de-sac; i
oblique fibres
which form
tinuation of
cular fibres
gullet (œ) an
from the left
the cardia,
merging i
deeper circul
with which
they entirely

It is connected with the muscular coat by means of intervenin

s layer so loosely as to allow of considerable movement or displace-
In consequence of this, and of the want of elasticity of the
s membrane, the internal surface of the stomach, when that organ
n empty or contracted state, is thrown into numerous convoluted
, *rugæ*, which are produced by the wrinkling of the mucous,
er with the areolar coat, and are entirely obliterated by disten-
f the stomach. These folds are most evident along the greater
ure, and have a general longitudinal direction.
examining the gastric mucous membrane closely with the aid of a
s lens, it is seen to be marked throughout, but more plainly towards
yloric extremity, with small depressions which have a polygonal
, and vary from about $\frac{1}{200}$th to $\frac{1}{100}$th of an inch across, being
and more oblong near the pylorus. They are the enlarged mouths
tubular glands with which the mucous membrane of the stomach
ed.

rds the pyloric region of the stomach these depressions are larger and
, and their margins are elevated into pointed processes, which might be
ed to rudimentary villi, but the perfect forms of those appendages exist
n the small intestine, and make their appearance in the duodenum, imme-
y beyond the pylorus.

ithelium of the surface.—The thick stratified epithelium of the
agus passes abruptly at the cardia into a simple layer of columnar
elium, which completely covers the inner surface of the stomach,

514.—EPITHELIUM OF THE SURFACE OF THE STOMACH EXAMINED FRESH (Heidenhain). HIGHLY MAGNIFIED. Fig. 514.

xtends to a variable distance into the mouths of
astric glands. The transition of the stratified
the columnar epithelium occurs quite suddenly,
owermost columnar cells of the stratified epithe-
passing into the single columnar layer of the gastric surface, and
e other layers of the stratified epithelium ceasing abruptly.

e epithelial cells of the surface of the stomach differ in some respects from
olumnar epithelium of the intestine. They are more elongated in form, and
active conditions of the organ they exhibit two parts, the attached end of
ell being granular, the free part—that turned towards the inner surface of
rgan—occupied by a clear, muco-albuminous substance (mucigen). Moreover,
is no striated border as in the intestinal cells. The clear substance swells
discharged from the cell during digestion, leaving empty the part of the
which contained it, and a similar change is produced by water and various
reagents. Between the smaller ends of the columnar cells, small, round
al cells occur in greater or less number, sometimes in small nests (Watney).

astric glands.—As was first shown by Sprott Boyd, the surface of
stomach within the depressions above mentioned is dotted with small
d apertures, which are the openings of minute glandular tubules,
ed perpendicularly to the surface. On making a vertical section
he membrane, and submitting it to microscopic examination, it is
to consist almost entirely of these small tubules, arranged parallel
h each other. Each mouth or duct, together with the tubules which
n into it, constitutes a *gastric gland*.
ome of the glands may be simple, consisting of a single tubule

throughout, but most are cleft into two or three tubules, or the branching of these, eventually into six or eight. The gla externally a basement membrane, composed of flattened cells joi to edge, and with processes which on the one side join the tissue of the mucous membrane, and on the other side, more extend in amongst and support the enclosed epithelium cells.

Two kinds of glands are distinguished, which differ from one both in the character of the enclosed cells, and, it is believed nature of their secretion. Those of the one kind (fig. 5 simpler in structure than the others, and being found most nu in the pyloric region, they have been named *pyloric glands*. T

Fig. 515.

Fig. 515.—A PYLORIC GLAND, FROM A SECTIO DOG'S STOMACH (Ebstein).

m, mouth ; *n*, neck ; *tr*, a deep portion of cut transversely.

distinguished by the large size and d the gland-mouth as compared with the which open into it, and by the characte epithelium lining the tubules. The n the gland is lined throughout by an epi which is continuous with and similar columnar epithelium which covers the surface of the stomach. But in the tu the gland the lining cells are shorter a cubical, and are uniformly finely granular t out ; moreover they are filled with secret different nature from that of the epithelium.

Amongst the cells of these glands there a sionally found others which are characterise coming darkly stained with osmic acid (Nu They were supposed to represent the parietal the cardiac glands (see below), but this is not the case.

In the glands of the second kind (fig 517)—which may be termed from the po the stomach where they occur most num the *cardiac glands* (fundus-glands of Heid oxyntic * glands of Langley)—the mouth, lined with epithelium like that of the is comparatively short, and into it the two, three or more tubules which are lined throughout and almo with short columnar or polyhedral cells ; these cells are in most similar to the secreting cells of the pyloric glands, but are mu coarsely granular. They were termed by Heidenhain the *parie* of the glands ; they are also known as the *central cells*. Betwee cells and the basement membrane of the tubule other cells of a

* From ὀξυς, acid ; since they contain the cells which produce the acid of secretion.

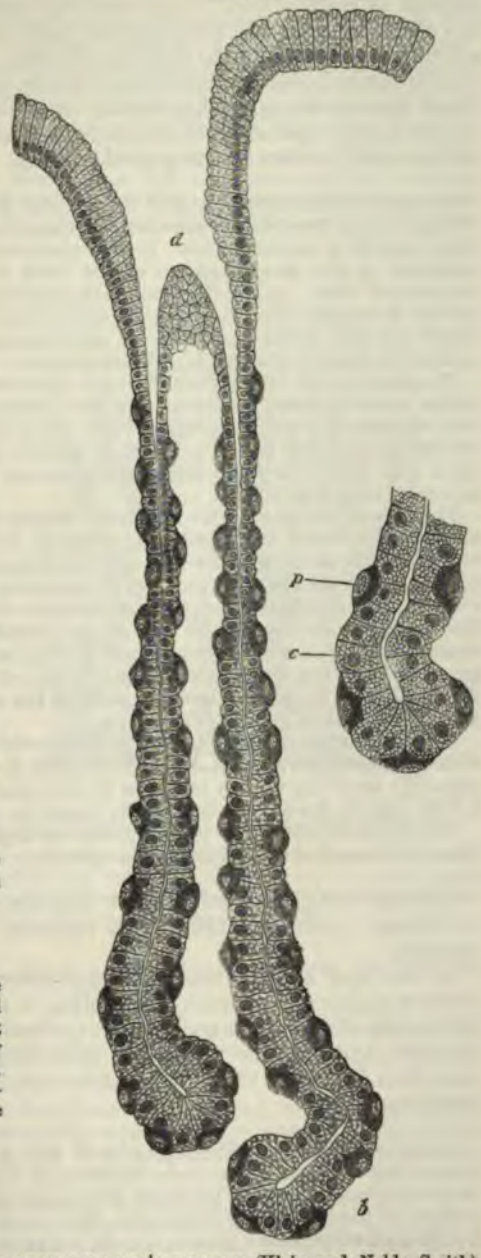
Fig. 517.

g. 516.

CARDIAC GLAND OF
M, FROM THE BAT'S
Langley).

preparation.

epithelium of the
neck of the gland
and parietal cells;
ndus, occupied only
or central cells,
the granules accu-
ds the lumen of the



-A CARDIAC GLAND FROM THE DOG'S STOMACH (Klein and Noble Smith).
fied.
mouth of the gland; *b*, base or fundus of one of its tubules. On the right
tubule *more highly magnified*; *c*, central cell: *p*, parietal cell.

nature are interpolated in the cardiac glands. These are the *super* *parietal* or *oxyntic cells*. They were long thought to be the only c the cardiac glands, and were on that account known as "peptic a term which must now be entirely discarded.

The parietal cells are rather more closely arranged in the neck gland than elsewhere. They usually cease abruptly at the upper p the neck, but occasional cells may be found under the columnar epith of the mouth or even of the general surface.

In some animals (porpoise, pig) the parietal cells lie each in a spec formed by the basement membrane, and communicating with the rest gland only by a narrow orifice. In the glandular stomach of birds th secondary tubules which lead out of the main tubule, this alone being by principal cells. In the frog and other amphibia the cardiac glands ha parietal or oxyntic cells, the principal cells being altogether absent, but containing cells which are similar in appearance and function to the pa cells of the stomach are found in the œsophagus.

The parietal cells have a finely granular appearance in the fresh condit in the gland hardened in alcohol are much darker and more granular l This appearance is due, according to Klein, not to the presence of actual gr within the cells, but to the existence of a close and uniform intracellula work (fig. 517). They are very readily stained by many colouring m especially by aniline blue.

The cells of the gastric glands undergo changes during the functional a of the organ which are strictly comparable to the changes that have be scribed in the cells of the serous salivary glands. The principal cells cardiac glands—which during rest are in some animals granular throughout, others have a small outer zone clear of granules—become distinctly differe into two zones during activity, some of the granules becoming dissolved an charged with the secretion, and the rest tending towards the lumen of the so as to leave the outer half or third of the cell clear of granules (fig. After digestion has ceased the outer parts of the cells become again partia wholly occupied by granules (Langley).

Both the central cells and the parietal cells undergo, according to Heide a change of size during digestion, becoming at first somewhat enlarged an sequently shrinking to even less than their original volume. The change a little later in the parietal than in the central cells.

The secreting cells of the pyloric glands undergo changes which are simi those of the central cells of the cardiac glands.

Between the glands and at their base the mucous membrane con of delicate connective tissue with retiform lymphoid tissue in amount.

A thin layer of plain muscular tissue (*muscularis mucosæ*) bound mucous membrane externally, separating it from the submucous ti It consists of more than one stratum (an outer longitudinal and an circular), and is better marked in some animals than in man. O pass from it between the gastric glands towards the surface of the m membrane.

Lymphoid follicles.—The stomachs of young persons sometimes pre mammillated aspect, due to little elevations of the surface, which are pr by local accumulations of lymphoid tissue, and somewhat resemble the s follicles of the intestine in appearance. The lymphoid accumulations in q are situated amongst the glands, and do not extend into the submucous they are not so distinctly circumscribed as those of the intestine, but fade the surrounding retiform tissue. They are most numerous at the junction stomach and small intestine (Watney).

nd Nerves.—The stomach is a highly vascular organ. Its *arterial* rived from all three divisions of the cœliac axis, reach the stomach folds of the peritoneum, and form, by anastomosing together, two erial arches, which are placed along its two curvatures. After rami- n the several coats and supplying them with blood (especially giving s capillaries to the muscular coat) and after dividing into very small e submucous areolar tunic, the ultimate arterial branches (fig. 518, *a*) ucous membrane, and ramifying freely, pass between the tubuli; rm a plexus (*d*) of fine capillaries upon the walls of the tubules; his plexus larger vessels pass into a coarser capillary network nouths of the glands. The *veins*, fewer in number than the arteries, he latter network, and take an almost straight course (*c*, *c*) through

Fig. 518.

Fig. 519.

518.—PLAN OF THE BLOOD-VESSELS OF THE STOMACH (from Brinton).

rteries passing to break up into the fine capillary network, *d*, between the oarser capillary network around the mouths of the glands; *c*, *c*, veins passing wnwards from the superficial network; *e*, larger vessels in the submucosa. in the deeper parts do not anastomose as here represented.

LYMPHATICS OF THE HUMAN GASTRIC MUCOUS MEMBRANE, INJECTED (from Lovén).

es are only faintly indicated; *a*, muscularis mucosæ; *b*, plexus of fine vessels nds; *c*, plexus of larger, valved lymphatics in submucosa.

membrane between the glands. After piercing the muscularis mucosæ g a wide venous plexus in the submucous tissue, they return the residual the splenic and superior mesenteric veins, and also directly into the

hatics are very numerous. As shown by Lovén, they arise in the mbrane (fig. 519) by a dense network of lacunar spaces, situated be- amongst the gland-tubuli, which, as well as the blood-vessels, in they enclose in sinus-like dilatations. Near the surface of the the lymph is collected into vessels which form loops or possess dilated ; these vessels are less superficial than the blood-capillaries, although

the lacunar spaces extend as far as the basement membrane of the sur
the deeper part of the mucous membrane the interglandular lymph
into a plexus of fine vessels (*b*), immediately underlying the tubula
then piercing the muscularis mucosæ (*a*), they form a coarser, mo
seated network (*c*) in the submucous coat, the vessels of this netw
provided with valves. Thence efferent lymphatics proceed and, piercing
cular coats, follow the direction of the blood-vessels beneath the peri
vestment, and traverse lymphatic glands found along the two curv
the stomach.

The *nerves*, which are large, consist of the terminal branches of
pneumo-gastric nerves, belonging to the cerebro-spinal system, and of o
the sympathetic system, derived from the solar plexus. The left pneu
nerve descends on the front, and the right upon the back of the
Numerous small ganglia have been found by Remak and others on
pneumo-gastric and sympathetic twigs. The nerves form gangliated
both between the layers of the muscular coat and in the submu
Their ultimate ending has not been traced.

The pylorus.—While there is no special apparatus at th
orifice of the stomach for closing the passage from the œsoph
opening at the pyloric end, leading from the stomach into
denum, is provided with a sphincter muscle. On looking into th
end of the stomach, the mucous membrane is seen projecting
form of a circular fold, called the *pylorus*, leaving a corresp
narrow opening (fig. 533, *p*). Within this fold are circular
fibres, belonging to the general system of circular fibres
alimentary canal, which are here collected in the form of a stro
whilst the longitudinal muscular fibres and the peritoneal c
over the pyloric fold to the duodenum, and do not enter into it
tion (fig. 512). Externally the pylorus may be easily felt, like
ened ring, at the right end of the stomach, where also a slight
constriction is visible. Internally its opening is usually circu
less than half an inch across, so that it is the narrowest part of th
alimentary canal.

Occasionally the orifice is oval, and it is often placed a little to
Sometimes the circular rim is imperfect, and there are found inst
crescentic folds, placed one above and the other below the passage (H
and, lastly, there is occasionally but one such crescentic fold.

When the sphincter is contracted the longitudinal fibres covering it a
inwards, and these, if they contract at the same time that the sphincte
relaxes, will tend to dilate the orifice.

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and Journ. of Physiol. III., 1882.

THE SMALL INTESTINE.

e **small intestine** (fig. 520 D, J, I) commences at the pylorus, after many convolutions terminates in the large intestine. It res on an average about twenty feet in length in the adult, and ally becomes slightly narrower from its upper to its lower end. nvolutions occupy the middle and lower part of the abdomen, and

Fig. 520.

20.—DIAGRAM OF THE ABDOMINAL PART OF THE ALIMENTARY AL (Brinton).

e cardiac, and P, the pyloric end stomach (this organ is represented horizontal a position); D, the um; J, I, convolutions of the intestine; CC, cæcum, with the orm process; AC, ascending, TC, erse, and DC, descending colon; moid flexure; R, rectum; A, anus.

rrounded by the large intes- They are connected with back of the abdominal y, and are held in their ion by a fold of the peri- m, named the mesentery, by numerous blood-vessels nerves.

e small intestine is arbitra- ivided into three portions, h have received different es; the first ten or twelve es immediately succeeding he stomach, and compre- ling the widest and most l part of the tube, being d the *duodenum*, the upper -fifths of the remainder being ed the *jejunum*, and the r three-fifths the *ileum*. There are no distinct lines of demarcation ween these three parts, but there are certain peculiarities of connec- and certain differences of internal structure to be observed in com- ing the upper and lower ends of the entire tube, which will be ted out after it has been described as a whole.

STRUCTURE OF THE SMALL INTESTINE.

he small intestine, like the stomach, is composed of four coats, viz., serous or peritoneal, muscular, areolar, and mucous.

he external or **serous coat** almost entirely surrounds the intestinal in the whole extent of the jejunum and ileum, leaving only a narrow rval behind, where it passes off and becomes continuous with the layers of the mesentery. The line at which this takes place is ed the *attached* or *mesenteric border* of the intestine. The duodenum, he other hand, is but partially covered by the peritoneum.

The **muscular coat** consists of two layers of fibres; an o tudinal, and an inner or circular set. The *longitudinal* fibres an entire but comparatively thin layer, and are most obvious alo border of the intestine. The *circular* layer is thicker and mor

The muscular tunic becomes gradually thinner towards the lower small intestine. It is pale in colour, and is composed of plain musc the cells of which are of considerable length. The progressive con these fibres, commencing in any part of the intestine, and advancing ward direction, produces the peculiar *vermicular* or *peristaltic* mo which the contents are forced onwards through the canal. In the of the tube the circular fibres are mainly concerned, the longitu tending to produce dilatation (Exner); and those found along the of the intestine may have the effect of straightening or unfolding its convolutions.

The **submucous coat** of the small intestine is a layer of are of a loose texture, which is connected more firmly with the mu with the muscular coat.

Fig. 521.

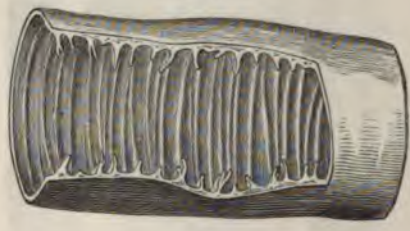


Fig. 521.—Portion INTESTINE LAID OPE THE VALVULÆ CONNIV ton).

The internal coat **membrane**, is ch by presenting all ove surface a finely floc shaggy appearance, li upon velvet, owing t thickly covered wit processes, named *villi*. It is one of the most vascular membra body, and is naturally of a reddish colour in the upper part of intestine, but is paler, and at the same time thinner, towards end. It is lined with columnar epithelium throughout its whe and next to the submucous coat is bounded by a layer of plain tissue (*muscularis mucosæ*); between this and the epithelium stance of the membrane, apart from the tubular glands which wil wards described, consists mainly of retiform tissue which supports vessels and lacteals, and encloses in its meshes numerous lymph-c

In the lining membrane of the small intestine, however, t besides small effaceable folds or rugæ, other permanent ones, whi be obliterated, even when the tube is forcibly distended. The nent folds are the **valvulæ conniventes**, or valves of (fig. 521). They are crescentic projections of the mucous m placed transversely to the axis of the bowel, each of them about one-half or two-thirds of the distance round the inte tube, and they follow closely one upon another along the intest largest are about 2½ inches long and ⅓ of an inch wide at or broadest part.

Large and small valvulæ conniventes are often found to alternate other. Some of them are bifurcated at one end, and others termina appearing as if suddenly cut off. Each consists of a fold of the m brane, that is, of two layers placed back to back, united toget submucous areolar tissue. They contain no part of the circular

udinal muscular coats. Being extensions of the mucous membrane, they o increase the absorbent surface to which the food is exposed.

re are no valvulæ conniventes quite at the commencement of the num ; a short distance from the pylorus they begin to appear ; beyond int at which the bile and pancreatic juice are poured into the duodenum re very large. regularly crescentic in form and placed so near to each

Fig. 522.

22.—VERTICAL SECTION OF INTESTINAL MUCOUS MEMBRANE OF THE RABBIT (slightly ed from Frey). 1/9.

villi are represented, in which the dilated lacteal is shown, in the other the vessels and lacteal are both njected, the lacteal white, ood-vessels dark : *a*, the vessels of the villi ; *a'*, ntal lacteal, which they join; illary blood-vessels in one of li ; *c*, small artery ; *d*, vein; epithelium covering the *g*, tubular glands or crypts berkühn, some divided down iddle, others cut more irre- y ; *i*, the submucous layer. cross section of three r glands more highly mag-

that the intervals between them are not greater than the breadth of one e valves ; they continue thus through the rest of the duodenum and along pper half of the jejunum ; below that point they begin to get smaller and er apart ; and finally, towards the middle or lower end of the ileum, having ally become more and more irregular and indistinct, sometimes even ring a very oblique direction, they altogether disappear.

he **villi,** peculiar to the small intestine, and giving to its internal ce the velvety appearance already spoken of, are small processes of mucous membrane, which are closely set on every part of the inner ace over the valvulæ conniventes, as well as between them.

he villi are usually tapered and flattened in form in the human ect (fig. 523) : some are cylindrical or finger-shaped (fig. 525), and sometimes an enlarged or clubbed extremity. Occasionally two or e are connected together at their base.

heir length varies from $\frac{1}{50}$th to $\frac{1}{16}$th of an inch or sometimes more. y are largest and most numerous in the duodenum and jejunum, and me gradually shorter, smaller, and fewer in number in the ileum. In upper part of the small intestine there are from 10 to 18 in a square imeter, and in the ileum from 8 to 14 in the same space. This ld give about 4 millions altogether (Krause).

villus consists of a prolongation of the proper mucous membrane. covered by columnar epithelium (fig. 524), and encloses a net- k of blood-vessels, one or more lymphatic vessels (lacteals), and a few itudinal plain muscular fibre-cells, these being all supported and together by retiform lymphoid tissue. Under the epithelium is a ment membrane composed of flattened cells, which on the hand are connected with the branched cells of the retiform tissue on the other *hand send processes* between the epithelium-cells.

Nerves have not yet been demonstrated in the villi, although probably not wanting. Each villus receives, as a rule, one small twig, which runs up the centre to near the middle of the villus, begins to break up into a number of capillaries (fig. 523). T

Fig. 523.

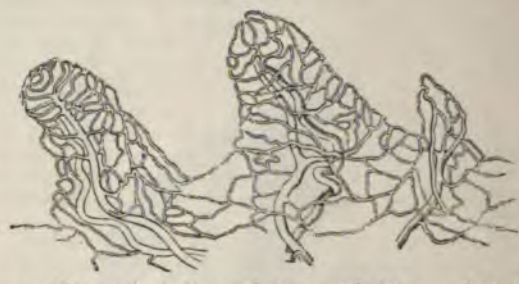


Fig. 523.—Ma... OF THE BL... OF THE ... VILLI.

The drawing ... from a prepara... by Lieberkühn, ... belonging to ... small artery an... the intermedia... network.

near the surface, beneath the epithelium and limiting membran... capillary network, from which the blood is returned for the mos... a single *vein*, which in man commences near the tip of the vi... passes through the mucous membrane into the submucosa wit... ceiving lateral twigs. The general arrangement of the vascula... of the villi varies considerably in different animals.

The lacteal lies in the centre of the villus (figs. 522, 524), a... the smaller villi usually a single vessel, with a closed and s...

Fig. 524.

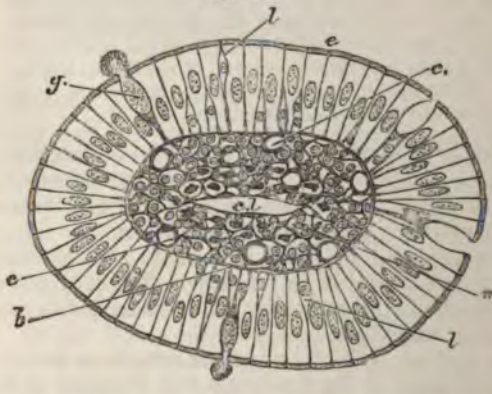


Fig. 524.—Cross ... A VILLUS OF ... INTESTINE. (...

e, columnar epith... goblet cell, its muc... partly exuded; *l*, ... puscles between th... lium-cells; *b*, base... brane; *c*, blood-c... *m*, section of plain ... fibres; *c.l*, central ...

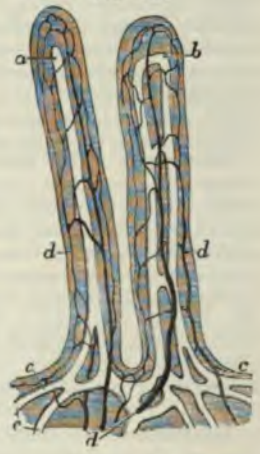
expanded extrem... of considerably ... diameter than t... laries of the bloo... around. Acco... the observati... Teichmann, there are never more than two intercommu... lacteals in a single villus in the human subject (fig. 525, *b*); ... he and Frey found a copious network in the villi of the shee... the lymphatics elsewhere, the lacteals in the villi are bound... delicate layer of flattened epithelial cells. These are connec... the branched cells and cell-spaces of the tissue of the villus, ... again with the flattened cells which form the basement me... from the latter, prolongations extend between the epithel... towards the surface.

The muscular tissue within the villus was discovered by Br... consists of a thin stratum of plain fibre-cells disposed longi...

l the lacteal; on being stimulated in animals, they produce an is retraction of the villus.

muscular tissue is a prolongation from the muscularis mucosæ; the ells at the sides and towards the end of the villus pass from the lacteal ttached to the basement membrane; usually their attachment to this is a connective tissue corpuscle filling up the interval (Watney).

Fig. 525.



5.—Injected lacteal vessels in two villi he human intestine. 100 diameters (Teichn).

lacteals are represented as filled with white subnd the blood-vessels with dark. *a*, *b*, the lacteal single in one villus and double in the other; *c*, rizontal lacteal vessels with which those of the mmunicate; *d*, the blood-vessels, consisting of rteries and veins with capillary network between.

e columnar epithelium cells (figs. 526, which cover not only the villi but also the f the surface of the intestine and extend the tubular glands have already been bed under the head of "Epithelium" p. 43 to 45).

y are set upon the surface of the basement rane often by a somewhat flattened extremity. e never been able to detect any continuity en their attached extremity and the branched corpuscles of the retiform of the villus, which has often been supposed to exist; on the contrary the lium separates with the greatest readiness from the subjacent tissue, and always with a simple truncated extremity, sometimes pitted but never branched. (E.A.S.)

ongst the ordinary epithelium-cells are others (fig. 524, *g*), the outer half of

Fig 526.

Fig. 527.

g. 526.—Columnar epithelium cells of the rabbit's intestine. (E. A. S.)
e cells have been isolated after maceration in very weak chromic acid. They are vacuolated, and one of them (2) has a fat-globule near its attached end; the striated r (*str.*) is well seen, and the bright disk separating this from the cell-protoplasm; cleus with intranuclear network; *a*, a thinned out wing-like projection of the cell probably fitted between two adjacent cells.

Fig. 527.—A row of columnar cells from an intestinal villus of the rabbit. (E. A. S.)
striated border; *w*, smaller cells between the epithelium cells, probably of the of lymph-corpuscles.

is filled with mucigen, and in some of these the mucus has become discharged the cell, and the free end is *ruptured* (goblet-cells, see p. 44). The number

of cells containing mucus varies much in different animals and per
different conditions in the same animal. There are comparatively
glands of the small intestine. During digestion of a meal contain
epithelial cells become turbid with minute oil-droplets in their in
at a subsequent stage branched cells within the tissue of the villus
vaded with similar fatty particles, and eventually the central lacte
filled with them. There has been much difference of opinion as t
taken by the fatty particles within the villus. It is possible that th
lymph-corpuscles which are found so abundantly within the tissue of
and even amongst the epithelium-cells of the surface, play an important
transference of the particles from the epithelium-cells to the lacteal; an
amount of lymphoid tissue in the lower end of the small intestine may be
to a greater power of fat absorption in that part of the gut. In the tran
carbon particles in the lungs from the interior of the alveoli to the lymph
at least in part is due to the activity of amœboid cells, we have an analogo

Other views which have been taken are (1) that the passage
through the branched connective tissue corpuscles of the villus, t
assumed to be in direct continuity with the fixed ends of the epit
(which is certainly not the case), and (2) that the fat does not t
epithelium-cells at all, but passes wholly between them and is taken u
reticulum (not a cell-network) which extend from the interspaces b
epithelium-cells through the tissue of the villus to be attached to t
the lacteal (Watney). There is, however, a difficulty in co
mechanical explanation of the passage of the fat particles along the
which Watney describes. It must be admitted that further investi
necessary for the elucidation of this problem.

Glands.—Two kinds of small secreting glands open on the
face of the intestine, viz., the crypts of Lieberkühn, and
glands, the last being peculiar to the duodenum. In addition
numerous lymphoid nodules are found, which are either scat
isolated (solitary glands) or collected into patches (Peyer's glan

The **crypts of Lieberkühn,** the smallest but most numerou
glandular structures, are found in every part of the small
opening on the surface between the villi (fig. 522, *g*). They

Fig. 528.

Fig. 528.—LYMPHOID OR RETIF
OF THE INTESTINAL MUCOUS M
THE SHEEP (from Frey). MA
DIAMETERS.

Cross section of a small fragm
mucous membrane, including one
of Lieberkühn and parts of severa
cavity of the tubular glands or cr
of the lining epithelial cells; *c*, t
or retiform spaces, of which some
and others occupied by lymph-cell

minute tubes, closed at thei
extremity which is slightly
and placed more or less perp
to the surface, upon which
sometimes two or three together. The crypts of Lieberkü
length from the $\frac{1}{50}$th to the $\frac{1}{120}$th of an inch, and their d
about $\frac{1}{600}$th of an inch. They are longest in the duodenum.
of the tubes are formed of a basement membrane, lined with
epithelium, (fig. 528).

unner's glands are small compound acino-tubular glands, which
n the duodenum, where they are most numerous at the upper end,
eral occupying thickly a space extending from one to two inches
d the pylorus. A few of them are said also to be found quite at
mmencement of the jejunum. They are imbedded in the sub-
s coat, and may be exposed by dissecting off the muscular coat
he outside of the intestine. In structure they somewhat resemble
all glands which are found in various parts of the lining membrane
e mouth and elsewhere, each consisting of a number of tubular
ll, connected by the terminal ramifications of the duct, which latter
ates the muscularis mucosæ, and opens upon the inner surface of
testine. In sections through the pylorus the glands of Brunner
r like direct continuations of the pyloric glands of the stomach
ney), which they closely resemble in structure, but are somewhat
complicated and more deeply seated.

e solitary glands are soft, white, rounded, and slightly prominent
s about the size of a millet-seed, which are found scattered over
mucous membrane in every part of the small intestine. They are
l as well at the mesenteric as at the free border, both between and
the valvulæ conniventes, and are rather more numerous in the
r portion of the bowel. These so-called glands are in structure
ar to the lymphoid nodules of various parts already described, con-
g of clumps of dense retiform tissue, the meshes of which are
ly packed with lymph-corpuscles and pervaded by fine capillaries.
are here and there united at the sides with the surrounding
phoid tissue, but are at most points distinctly marked off from it,
y owing to the fact that their supporting retiform tissue becomes
r and finer, partly owing to their being surrounded by a rich
s of lymphatic vessels; or they even hang, as it were, into
mphatic (or lacteal) sinus, which may entirely surround the nodule,
pt next the inner surface of the intestine. The epithelium over the
le often has a large number of lymph-corpuscles between the
helial cells. The base of the nodule or follicle is situated in the
mucous tissue; but it extends upwards, through the muscularis
osæ, into the mucous membrane, causing a bulging of this towards
interior of the gut (as in fig. 531, *d d*). The prominent part of the
cle sometimes has villi upon it, and, placed around very irregularly,
een the mouths of the crypts of Lieberkühn.

he agminated glands or **glands of Peyer** (who described them in
7), are groups or patches of lymphoid nodules. The groups have
blong figure (fig. 529), and vary from half an inch to two or even
inches in length, being about an inch, or rather less, in width:
are placed lengthways in the intestine at that part of the tube
t distant from the mesentery; and hence, to obtain the best
of them, the bowel should be opened by an incision along its
ched border.

he lymphoid nodules which by their aggregation make up a Peyer's
h are in almost all respects similar to the solitary glands above
ribed. As a rule their surface is free from villi, and the crypts
ieberkühn are collected in circles around them. Fine blood-vessels
listributed abundantly on the exterior of the follicles, and give off
finer capillary branches, which, supported by the retiform tissue,
lisposed principally in lines converging to the centre (fig. 530).

The lacteal plexuses, which are abundant in the whole ex
intestine, are especially rich where they surround the follicles

Fig. 529.

Fig. 529.—A SMALL PATCH OF PE
FROM THE ILIUM. SLIGHTLY MAGNIF

glands (fig. 531), often formi
around them, as in the case of t
follicles above described.

In all, from twenty to thirty of
patches may in general be found;
persons dying in health, as many
have been observed. They are larg
at shorter distances from each othe
part of the ileum; but in the uppe
that intestine and in the lower
jejunum the patches occur less
become smaller, and are of a ne
form; they may, however, be disc
sionally in the lower portion of th
Still smaller irregularly shaped clus
follicles are sometimes found scatte
out the intestine.

The glands of Peyer are best m
young subject. After middle life
less obvious, and disappear almost
in advanced age, their remains being
cated by dark colouration of
membrane.

Vessels and Nerves.—The branches of the mesenteric artery, hav
the attached border of the intestine, pass round its sides, dividing in

Fig. 530.

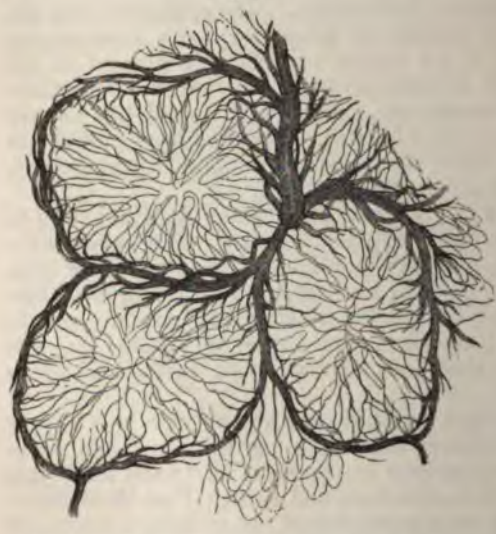


Fig. 530.—Po
INJECTED P
(from Kolli
NIFIED.

The drawing
from a prepara
Frey of the int
rabbit. It re
fine capillary ne
ing from the
blood-vessels i
rior of thre
nodules.

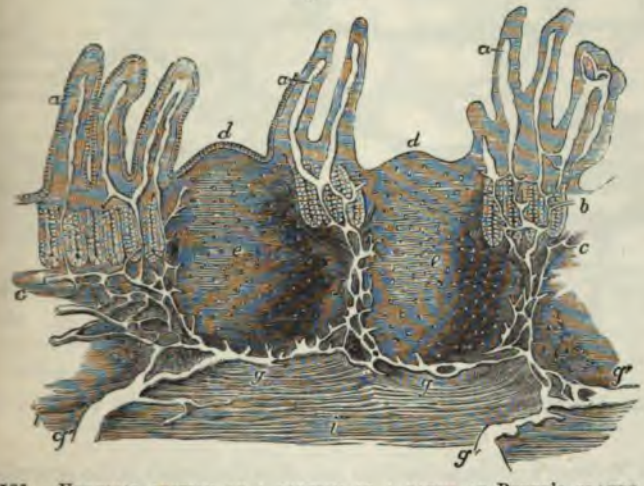
ramifications
quently anast
its free borde
the larger b
immediately
serous coat;
pierce the mu
supplying it
as they pass,
in the submu
layer, so as
close netw

which still smaller vessels pass on into the mucous coat, and termi
capillary network of the folds, villi, and glands of that membran

ries of the muscular coat are arranged in two layers of oblong meshes, correspond in direction with the longitudinal and circular muscular fibres. ins accompany the arteries.

lymphatics of the intestine (lacteals) may be conveniently distinguished e of the mucous membrane, and those of the muscular coat. Those of coous membrane form a copious plexus (fig. 531) which receives the vessels of the villi and pervades both the mucous and submucous layers he latter being of considerable size, and forming, as before mentioned, a lexus or a sinus around the base of each lymphoid follicle. Another set of atics lies under the peritoneal coat, and is especially developed along a strip at the attachment of the mesentery. In the muscular coat, the main is situated between the circular and longitudinal layers of fibres (fig. 532, *l*); ere are likewise close plexuses threading the whole thickness of the muscu- ll. These lymphatics of the muscular coat are in complete continuity with of the mucous membrane, and pass into larger vessels at the mesenteric which again run into the lacteal vessels of the mesentery.

Fig. 531.



531.—VERTICAL SECTION OF A PORTION OF A PATCH OF PEYER'S GLANDS, WITH THE LACTEAL VESSELS INJECTED (after Frey). 32 DIAMETERS.

e specimen is from the lower part of the ileum : *a*, villi, with their lacteals left ; *b*, some of the tubular glands; *c*, the muscular layer of the mucous membrane ; pola or projecting part of the nodule ; *e*, their central part ; *f*, the reticulated l vessels occupying the lymphoid tissue between the nodules, joined above by cteals from the villi and mucous surface, and passing below into *g*, the reticulated ls under the follicles, which again pass into the large, efferent lacteals, *g'* ; *i*, part muscular coat.

e *nerves* of the small intestine are chiefly derived from the superior nteric plexus. This plexus is formed by nervous branches, from the cœliac s, the semilunar ganglion, and from the vagus nerve. The plexus and form branches into which it divides cling at first very closely to the larger ions of the superior mesenteric artery, and, dividing similarly with the fications of the arteries, the branches of the nerves, retaining still a wide form arrangement, pass onwards to the different parts of the intestine between wo folds of the mesentery, and finally, separating somewhat from the blood- ls, reach the intestine in very numerous branches to be distributed in its

Passing first between the longitudinal and circular layer of the muscular they here form a close gangliated plexus throughout the whole extent of

the intestine (fig. 532, *n*, as exhibited under a low power). This, which as the *plexus of Auerbach*, or the *plexus myentericus*, and which is p composed of non-medullated fibres, gives off fine branches to the substance, these first forming a smaller plexus amongst the muscul Other larger branches pass between the circular bundles of fibres to submucous layer, where they form a second gangliated plexus (*Meissner*), the threads of which are much finer than those of the inte plexus.

Fig. 532.

Fig. 532.—Lymphatic plexus (*l*) and nervous plexus (*n*) in the muscula the intestine (Auerbach).

From Meissner's plexus nerve-fibres pass to be distributed to the musc of the mucous membrane, breaking up into fine fibrils which take the of the fibre-cells of this layer, whilst other fine fibrils form a comparati plexus in the proper tissue of the mucous coat, and appear to send towards the epithelium, but the further course of these has not been tra

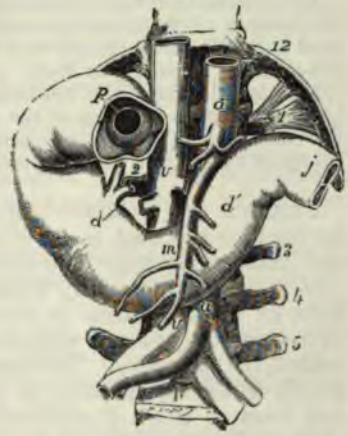
SPECIAL CHARACTERS AND CONNECTIONS OF THE SEVERAL OF THE SMALL INTESTINE.

Duodenum.—This is the shortest and widest part of the sm tine. In length it measures about 10 inches, and in diameter between 1½ and 2 inches. In its course it describes a single lar of an almost circular shape but moulded over the front of the column (see fig. 550, p. 635); the termination in the jejunum in the empty condition of the stomach, only a little to the le commencement (Braune). The concavity embraces the hea pancreas.

It has no mesentery, and is covered only partially by the peri Its muscular coat is comparatively thick, and its sub-muco towards the pylorus is the seat of the glands of Brunner,

l. The common bile-duct and the pancreatic duct open into
of the intestinal canal.
portions of the duodenum are described by anatomists.
irst, or *superior* portion, about two inches long, extends from
rus upwards, backwards, and to the right, as far as beneath
c of the gall-bladder, where it bends suddenly downwards.
t portion of the duodenum is for the most part moveable,

Fig. 533.



-VIEW OF THE DUODENUM FROM
slightly altered from Luschka). $\frac{1}{4}$

twelfth dorsal vertebra and rib ; 1,
nsverse processes of the first, third,
d fifth left lumbar vertebræ ; 2,
second on the right side ; *a*, *a*, the
aorta above the cœliac axis and also
furcation ; *m*, superior mesenteric
v, the vena cava above the renal
ear the bifurcation ; *p*, placed on
rt of the duodenum, points to the
fice seen from the side next the
f which a small part is left con-
the intestine ; *d*, on the descend-
nd part of the duodenum, indicates
ation of the common bile-duct and
atic duct ; *d'*, the third or oblique
duodenum ; *j*, the commencement
unum. (This is represented as
r to the left, instead of curving
is actually the case.)

sted by peritoneum like the stomach. Above, and in front of
e liver and gall-bladder, and it is commonly found stained by
lation of bile from the latter a few hours after death. Behind
biliary duct, with the blood-vessels passing up to the liver.
econd, or *descending* portion, commencing at the bend below the
the gall-bladder, passes downwards as low as the second or third
ertebra, where the bowel turns across to the left to form the
rtion. This part of the duodenum is invested by the perito-
its anterior surface only,—the posterior surface being con-
o the right kidney, the renal vessels and the vena cava by
issue. In front is the transverse colon and mesocolon, which
uous with the peritoneal covering of the duodenum. To the
e head of the pancreas (see fig. 551, p. 635), which adapts itself to
e of the intestine on that side, and, according to Verson, some of
itudinal muscular fibres of the gut are intercalated amongst the
us lobules of the gland. The common bile-duct descends
he left border of this part of the duodenum, and the pancreatic
ompanies it for a short distance. In the interior the valvulæ
ites appear numerously ; and a downwardly projecting, papillary
e of the mucous membrane is found immediately below one of
out four inches below the pylorus, on the inner and back part
ntestine, at the apex of which is seen the common orifice of the
nd pancreatic ducts.
hird, *transverse* or oblique portion (*d'*), somewhat the longest and
st, beginning on the right of the third lumbar vertebra, crosses in
the second vertebra *obliquely from right* to left, finally making a

the jejunum. It is maintained, at that point, in its position band descending from the left crus of the diaphragm and cœliac axis. According to Treitz, plain muscular fibres c sources to this part of the duodenum. In subjects in wh large and dilated, the curve of the duodenum may descen iliac crest, but, owing to the support given by the band al extremity maintains a uniform position.

JEJUNUM AND ILEUM.—The *jejunum*, originally having been supposed to be empty after death, follo and includes the upper two-fifths of the remainder tine, while the succeeding three-fifths constitute th from its numerous coils or convolutions. Both th ileum are attached and supported by an extensive termed the *mesentery*. The mesentery of the small greatly frilled out in front to correspond in length and ileum to which it affords support, is attached p short border which extends from the level of attach verse colon immediately to the left of the middle lin the right iliac fossa, where the ileum falls into th widest part the length of the mesentery is from f between its vertebral and its intestinal border. Betv of peritoneum of which it consists, are placed, besides branches of the superior mesenteric artery and v nerves, lacteal vessels, and mesenteric glands. The jejunum are situated in part of the umbilical and left regions of the abdomen ; while the ileum occupies pa and right lumbar and iliac regions, together with th its lower part descends into the pelvis supported by From here it ascends obliquely to the right and son over the corresponding psoas muscle, and ends in the opening into the inner side of the commencement of The character of the intestine gradually changes fro lower end, so that portions of the two intestines resem

is probably connected with the persistence of a part of the vitelline early fœtal life. They are not to be confounded with hernial protrusions cous membrane, which may occur at any point.

Literature of the small Intestine.—*Verson*, in Stricker's Handbook, *ller*, in Ber. d. Sachs. Gesellsch., 1872 (blood-vessels); *Schwalbe*, in Arch. Anat., VIII., 1872 (Brunner's glands); *Heidenhain*, in Arch. f. mikr. Anat., 72 (Brunner's glands), and article in Hermann's Handb., 1881; *Thannhofer*, in Arch., VIII., 1873, and Med. Centralbl., 1876 (fat absorption); *H. Watney*, in ntralbl., 1874, and Phil. Trans., 1876 (structure of alimentary canal, and fat n); *Defois*, in Rev. d. sci. méd., 1874 (vessels); *Grützner*, in Pfluger's Arch., unner's glands); *Winiwarter*, in Wiener Sitzungsb., 1876 (lacteals); *Exner*, Sitzungsb., 1877 (action of longit. muscles); *Klose*, Dissert., Breslau, 1880 Lieberkühn); *Hoffmann*, Dissert., München, 1878 (solitary glands).

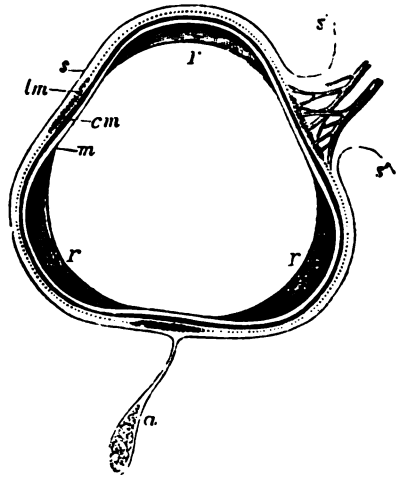
THE LARGE INTESTINE.

large intestine extends from the termination of the ileum to the It is divided into the cæcum (with the vermiform appendix), the and the rectum; and the colon is again subdivided, according to ction, into four parts, called the ascending, transverse, and descend- on, and the sigmoid flexure (fig. 520).

length of the large intestine is usually about 5 or 6 feet; being one-fifth of the whole length of the intestinal canal. Its diameter, for the most part greatly exceeds that of the small intestine, varies rent points from two inches and a half to about one inch and a It diminishes gradually from its commencement at the cæcum to mination at the anus; excepting that there is a well-marked dila- of the rectum just above its lower end.

outward form, the greater part of the large intestine differs

Fig. 534.



4.—Outline sketch of a section of the ascending colon (Allen ston). ⅔

ous covering; *s'*, *s'*, reflection of the attached border forming a ide mesentery, between the folds h the blood-vessels are seen pass- the colon; *a*, one of the appen- piploicæ hanging from the inner ; *l m*, indicates at the free border the three bands formed by the ing of the longitudinal muscular the dotted line continued from the e of these bands represents the der of the longitudinal muscular and the thick line within it l *c m*, represents the circular mus- layer; *m*, the mucous membrane flattened part; *r*, the crescentic or indentations which divide the

kably from the small intestine; for, instead of constituting an cylindrical tube, its surface is thrown into numerous sacculi, d off from each other by intervening constrictions, and arranged ee longitudinal rows, separated by three strong flat bands of longi- al muscular fibres. This sacculated structure is not found in the n.

STRUCTURE OF THE LARGE INTESTINE.

The large intestine has four coats, like those of the sto
small intestine, namely, the serous, muscular, submucous, and

The **serous coat** is for the most part similar to that of th
testine, except that, along the colon and upper part of the re
prolonged into numerous little projections, which enclose
amount of fat, and are termed *appendices epiplöicæ*.

Fig. 535.

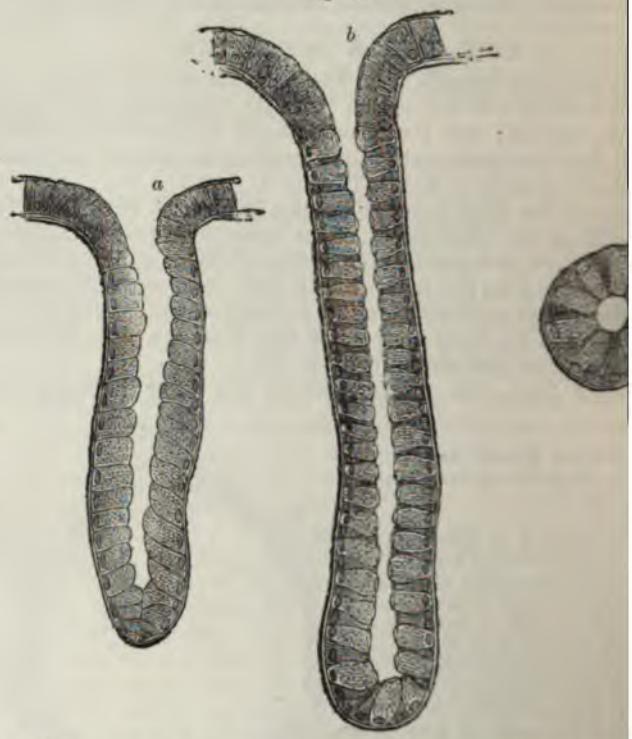


Fig. 535.—Glands of the large intestine. Magnified (from Heidenh
Klose).

a, of the rabbit; *b*, of the dog. *c*, transverse section of a gland of the dog

The **muscular coat**, like that of the other parts of the intesti
consists of external longitudinal and internal circular fibres.

The *longitudinal* fibres, although found in a certain amount
the intestine, are, in the cæcum and colon, more thickly colle
three remarkable flat longitudinal bands (fig. 534, *l m*; fig. 520)
bands, sometimes called the ligaments of the colon, are about
inch wide, and half a line thick; they commence upon the exte
the cæcum, at the attachment of the vermiform appendix, a
be traced along the whole length of the colon as far as the con

rectum, where they spread out, so as to surround that part of nal tube with a uniform layer of longitudinal muscular e of these bands, the *posterior*, is placed along the attached ie intestine; another runs along its *anterior* border, and, in rse colon, corresponds with the attachment of the great whilst the third band (*inner*) is found on the inner border ading and descending colon, and on the under border of the colon. It is along the course of this third band that the epiploicæ are most of them attached (fig. 534, *a*). Measured o end, these three bands are shorter than the intervening e tube; and the latter are thus thrown into the sacculi al-ioned: accordingly, when the bands are removed by dissection, are entirely effaced, and the colon, elongating considerably, cylindrical form. The transverse constrictions seen on the the intestine, between the sacculi, appear on the inside as s separating the cells, and are composed of all the coats. In rm appendix the longitudinal muscular fibres are disposed in a er.

ular muscular fibres form only a thin layer over the general he cæcum and colon, but are accumulated in larger numbers e sacculi. In the rectum, especially towards its lower part, fibres form a very thick and powerful muscular layer.

mucous or **areolar** coat resembles in all respects that of the ine.

ous membrane differs from that of the small intestine in

Fig. 536.

LOOD-VESSELS OF LARGE INTESTINE VERTICAL SECTION (Kölliker).

assing up from submucosa; *c*, vein apillary plexus, *b*, which surrounds the glands.

th and destitute of villi. View-lens, its surface is seen to be over by the orifices of nume-ar glands (*crypts of Lieberkühn*, 535), resembling those of the stine, but longer and more nd further distinguished from e large number of mucus-cells contain. Indeed in some l the cells of these glands und to be filled with mucus); in others every alternate ts this character, the cells be-of the ordinary columnar kind.

ds are stimulated to active secretion the mucus is discharged and assume the appearance of ordinary columnar epithelium-cells (Klose).

l over the whole large intestine *lymphoid nodules* are found, he solitary *glands of the small* intestine, but less prominent.

surface, in the same way as in the villi of the small i

Vessels and Nerves.—In the large intestine an arran
plexuses and venous radicles obtains, similar to that whic
in the stomach (fig. 536). The arrangement of the lymphat
same.

Nervous plexuses similar to those of the small intestine
muscular and submucous coats of the large intestine.

SPECIAL CHARACTERS AND CONNECTIONS OF THE
OF THE LARGE INTESTINE.

THE CÆCUM.—The *intestinum cæcum*, or *caput c*
part of the large intestine which is situated below th
ileum (fig. 520, cc). Its length is about 2½ inches,
nearly the same: it is the widest part of the large inte

The cæcum is situated in the right iliac fossa, imme
anterior wall of the abdomen. It is covered by the pe
below, and at the sides: but behind it is usually desti
covering, and is attached by areolar tissue to the fa
right iliacus muscle. In this case the cæcum is co
but in other instances the peritoneum surrounds it al
forms a duplicature behind it, called *meso-cæcum*.

Coming off from the inner and back part of the cæ
end, is a narrow, round, and tapering portion of the
the *appendix cæci*, or **vermiform appendix.** Th
process is usually about that of a large quill or rat
length varies from 3 to 6 inches, these dimensions
different cases. Its general direction is upwards an
the cæcum; and after describing a few slight turns
point. It is retained in its position by a small fo
which forms its mesentery. The cæcal appendix is
its extremity: and its cavity communicates with th
by a small orifice, sometimes guarded by a valvul

valve composed of two segments or folds. This is the *ileo-cæcal eo-colic valve:* it is also called the valve of Bauhin and the valve ulpius, although Fallopius had described it before either of those omists.

he ileum communicates with the colon by a narrow elongated slit-like ture, lying nearly transversely to the direction of the large intestine.

537.—VIEW OF THE ILEO-COLIC LVE FROM THE LARGE INTESTINE fter Santorini). ½

e figure shows the lowest part of the n, *i*, joining the cæcum, *c*, and the ding colon, *o*, which have been ed anteriorly, so as to display the colic valve; *a*, the lower, and *e*, the r segment of the valve.

Fig. 537.

e aperture is rounded and lened at its anterior end which urned slightly to the left, but posterior end is narrow, and nted. It is bounded above d below by two prominent milunar folds, which project wards towards the cæcum and on. The upper of these (fig. 7, *e*) is horizontal, the lower d larger (*a*) slightly oblique. each end of the aperture se folds coalesce, and are then prolonged as a single ridge on h side for some distance round the cavity of the intestine, form- the *frœna* or *retinacula* of the valve. The opposed surfaces of valvular folds which look towards the ileum, and are continuous h its mucous surface, are covered like it with villi; while their other faces, turned toward the large intestine, are smooth and destitute villi. When the cæcum is distended, the frœna of the valve are tched, and the marginal folds brought into apposition, so as com- ely to close the aperture and prevent reflux into the ileum, while at same time no hindrance is offered to the passage of additional tter from thence into the large intestine.

Each segment of the valve consists of two layers of mucous membrane, tinuous with each other along the free margin, and including between m, besides the submucous areolar tissue, a number of muscular fibres, tinued from the circular fibres of the ileum and of the large intestine. e longitudinal muscular fibres and the peritoneal coat take no part the formation of the valve, but are stretched across it uninterruptedly m one intestine to the other.

THE COLON.—The ASCENDING COLON, situated in the right lumbar l hypochondriac regions, commencing at the cæcum opposite to the -cæcal valve, ascends vertically to the under surface of the liver, near gall-bladder, where it proceeds forwards and then turns abruptly to left, forming what is named the *hepatic flexure* of the colon. The nding colon *is smaller than the* cæcum, but larger than the trans-

verse colon. It is overlaid in front by some convolutions of the ileum, and is bound down firmly by the peritoneum, which passes over its anterior surface and its sides, and generally leaves an interval in which its posterior surface is connected by areolar tissue with the fascia covering the quadratus lumborum muscle, and with the front of the right kidney. In some cases, however, the peritoneum passes nearly round it, and thus forms a distinct though very short meso-colon.

The TRANSVERSE COLON describes an arch, the convexity of which is turned towards the anterior abdominal wall; and it has accordingly been named the *arch of the colon*. It passes across from the right hypochondrium, through the upper part of the umbilical region, into the left hypochondrium. Sometimes it is found as low as the umbilicus or even lower. At each extremity it is situated deeply towards the back part of the abdominal cavity, but in the middle it curves forwards, and lies close to the anterior wall of the abdomen.

Above, the transverse colon is in contact with the under surface of the liver, the gall-bladder, the great curvature of the stomach, and the lower end of the spleen. Below it are the convolutions of the small intestine, the third portion of the duodenum being behind it. It is invested by the general peritoneum, which forms a separate fold for it, the *transverse meso-colon*, and in front it adheres to the lower fold of the sac of the omentum.

The DESCENDING COLON is continuous with the left extremity of the transverse colon by a sudden bend named the *splenic flexure*. At this bending there is found a remarkable fold of peritoneum, the *costo-colic* or *pleuro-colic ligament*, which stretches with a lunated free border to the colon from the diaphragm, opposite the 10th or 11th rib. As was pointed out by Haller, it supports the spleen although unconnected with that organ, and might be termed "sustentaculum lienis." The colon then descends almost perpendicularly through the left hypochondriac and lumbar regions to the left iliac fossa, where it ends in the sigmoid flexure. The peritoneum affords a covering to it only in front and at the sides, whilst behind it is connected by areolar tissue to the diaphragm, the quadratus lumborum, and the left kidney. It is usually concealed behind some convolutions of the jejunum.

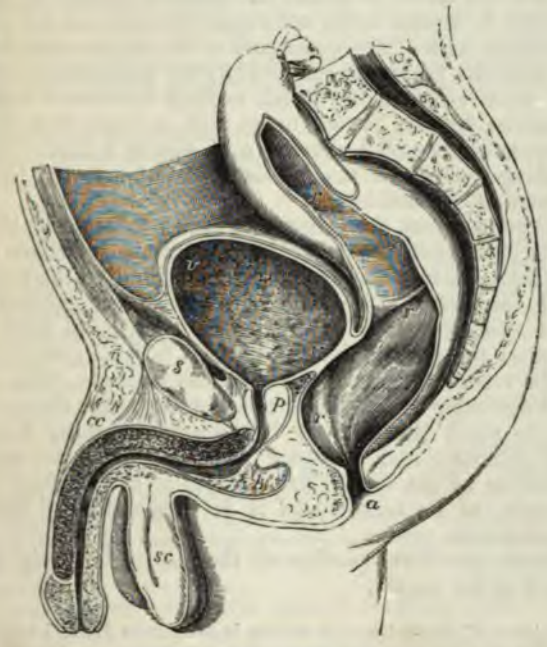
The SIGMOID FLEXURE of the colon, situated in the left iliac fossa, consists of a double bending of the intestine upon itself in the form of the letter S, immediately before it becomes continuous with the rectum at the margin of the pelvis opposite to the left sacro-iliac articulation. It is attached by a distinct meso-colon to the iliac fossa, and is very movable, falling into the pelvis when the bladder is empty. It is placed immediately behind the anterior wall of the abdomen, or is concealed only by a few turns of the small intestine. The sigmoid flexure is the narrowest part of the colon.

THE RECTUM.—The lowest portion of the large intestine, named the *rectum*, extends from the sigmoid flexure of the colon to the anus, and is situated entirely within the true pelvis, in its back part (fig. 538, *r*, *r*).

Commencing opposite the left sacro-iliac articulation, it is directed at first obliquely downwards, and from left to right, to gain the middle line of the sacrum. It then changes its direction, and curves forwards in front of the lower part of the sacrum and the coccyx, and behind the bladder, vesiculæ seminales and prostate in the male, and at the back of the cervix uteri and vagina in the female. Opposite the

e it makes another turn, and inclines downwards and backwards
a the anus. Seen from the front, the upper part of the rectum
s a lateral inclination from the left to the median line of the
sometimes passing beyond the middle to the right; and when
from the side (fig. 538), it offers two curves, one corresponding

Fig. 538.



g. 538.—VERTICAL SECTION OF THE PELVIS AND ITS VISCERA IN THE MALE (Allen Thomson, after Houston). ⅓

figure is introduced to illustrate the form, position, and relations of the rectum; hows the bladder and urethra with the pelvic inflection of the peritoneum over iscera: *r*, *r*, *r*, the upper and middle parts of the rectum, and at the middle e fold separating the two; *r*, *a*, the lower or anal portion; *v*, the upper part of ary bladder; *v'*, the base, at the place where it rests more immediately on the ; *p*, the prostate gland and prostatic portion of the urethra; *b*, the bulb; *c*, *c*, us cavernosum penis and suspensory ligament; *sc*, the scrotum; *s*, symphysis

he hollow front of the sacrum and coccyx, and the other at the end of the bowel, forming a shorter turn in the opposite direction.

ntestinum rectum, therefore, so called from its original description being from animals, is far from being straight in the human subject.

ike the rest of the large intestine, the rectum is not sacculated, smooth and cylindrical; and it has no separate longitudinal upon it. It is about eight inches in length, and at its upper rather narrower than the sigmoid flexure, but becomes dilated large ampulla or reservoir immediately above the anus.

flected forwards to ascend in the male upon the back of
the female on the back of the upper part of the vagina
In passing from the rectum to the bladder, the peritoneu
de-sac, the recto-vesical pouch, which extends downwar
intestine and the bladder to within an inch or more fr
the prostate, and is bounded above at each side by a lun
serous membrane, of which the left is almost always t
terior ligaments of the bladder).

Below the point where the peritoneum ceases to cover
is connected to surrounding parts by areolar tissue, w
loaded with fat. In this way it is attached behind to t
sacrum and the coccyx, and at the sides to the coccyg
ani muscles. In front, it is in immediate connection
gular portion of the base of the bladder (fig. 538, *v'*) ;
this, with the vesiculæ seminales ; and farther forwards,
surface of the prostate (*p*). Below the prostate, where t
downwards to reach the anus, it becomes invested b
the internal sphincter, and embraced by the levatores
which, as well as by the triangular ligament of the ure
ported. Lastly, at its termination it is surrounded b
sphincter ani muscle.

In the female, the lower portion of the rectum is fir
with the back of the vagina.

For convenience of description the rectum is sometimes divide
three parts ; the first or uppermost, about 3½ inches long, extend
of the 3rd sacral vertebra : the middle part (3 inches) from this
of the coccyx ; whilst the lowermost, about an inch and a half l
wards and downwards to the anus.

Structure of the Rectum.—The rectum differs in some respe
of the large intestine, in the structure of both its muscular and

The *muscular coat* is very thick : the external or longitudi
uniform layer around it, and near the lower end of the intesti
the external and internal sphincters, and end partly amongst t
muscles, partly in the skin of the anus. The internal or circu
more numerous towards the anus, where they form the internal
The longitudinal fibres are paler than the circular, but bot

folds were named by Morgagni the *columns* of the rectum. These columns contain longitudinal muscular fibres (apparently part of the muscularis mucosæ), which terminate both superiorly and inferiorly in elastic tissue (Treitz). Higher up in the intestine, the chief folds are transverse or oblique. Three prominent folds, larger than the rest, being half an inch or more in depth, and having an oblique direction in the interior of the rectum, have been pointed out specially by Houston. One of these projects backwards from the upper and fore part of the rectum, opposite the prostate gland; another is placed higher up, at the side of the bowel; and the third still higher. From the position and projection of these folds, they may more or less impede the introduction of instruments (Dublin Hospital Reports, vol. v.). Hermann and Desfosses describe convoluted glandular tubes lying between the muscular bundles of the internal sphincter and opening on to the surface of the mucous membrane close to the anus (Compt. rend., xc. 1880).

Vessels and Nerves of the Rectum.—The *arteries* of the rectum spring from three sources, viz., the superior hæmorrhoidal branches from the inferior mesenteric; the middle hæmorrhoidal branches from the internal iliac directly or indirectly; and, lastly, the external or inferior hæmorrhoidal branch from the pudic artery. The arrangement of the vessels is not the same throughout the rectum. Over the greater part the arteries penetrate the muscular coat at short intervals, supplying its layers as they pass through, and, at once dividing into small branches in the submucosa, form a network by their intercommunication. Towards the lower end, for four or five inches, the arrangement is different. Here the vessels, having penetrated the muscular coat at different heights, assume a longitudinal direction, passing in parallel lines towards the end of the bowel. In their progress downwards they communicate with one another at intervals, and they are very freely connected near the orifice, where all the arteries join by transverse branches of considerable size (R. Quain).

The *veins* are very numerous, and form a complex interlacement resembling that of the arteries just described, and named the *hæmorrhoidal plexus*. After following a longitudinal course upwards similar to that of the arteries which they accompany, they end partly in the internal iliac vein by branches which accompany the middle hæmorrhoidal artery, and partly in the inferior mesenteric vein. Hence, the blood from the rectum is returned in part into the vena cava, and in part into the portal system.

The *lymphatics* enter some glands placed in the hollow of the sacrum, or those of the lumbar series.

The *nerves* are very numerous, and are derived from both the cerebro-spinal and the sympathetic systems. The former consist of branches derived from the sacral plexus; and the latter of offsets from the inferior mesenteric and hypogastric plexuses.

THE ANUS AND ITS MUSCLES.

The *anus*, or lower opening of the alimentary canal, is a dilatable orifice, at which the mucous membrane and skin become continuous with each other. The skin around the borders of the anus, which is thrown into wrinkles during the closed state of the orifice, is covered with numerous papillæ, and is provided with hairs and large sebaceous follicles.

The lower end of the rectum and the margin of the anus are, moreover, embraced by certain muscles, which serve to support the bowel, and to close its anal orifice. These muscles, proceeding from within outwards, are, the internal sphincter, the levatores ani, the coccygei, and the external sphincter. The three last muscles have already been described in Vol. I.

The **internal sphincter muscle** is a muscular ring or rather belt, surrounding the lower part of the rectum, an inch above the anus, and extending over about half an inch of the intestine. It is two lines thick, and is paler than the external sphincter. Its fibres are continuous

above with the circular muscular fibres of the rectum, and, consists merely of those fibres more numerously developed t where, and prolonged farther down than the external lon fibres.

Kohlrausch describes a thin stratum of fibres between the mucous and the internal sphincter, these fibres having a longitudinal direction. to Henle this is nothing more than the longitudinal fibres of the mucosæ; but Kohlrausch gives it a distinct name, the sustentator tunic (corrugator cutis ani of Ellis). (Kohlrausch, Anat. und Phys. d. Beck Leipzig, 1854; Ellis, Illustrations of Dissections, London, 1865; *Rouz* i mikr. Anat., XIX. 1881; *Robin et Cadiat* in Journ. de l'anat., 1874.)

THE LIVER.

The **liver** is the largest gland in the body, and by far the m of the abdominal viscera. It measures about 10 or 12 inch versely from right to left, between 6 and 7 inches from its to its anterior border, and about 3½ inches from above downwa thickest, which is towards the right and posterior part. The bulk is 90 to 100 cubic inches. The ordinary weight is be and 60 ounces.

The liver is solid to the feel, and of a dull reddish-brown co frequently a dark-purplish tinge along the anterior margin.

According to the facts recorded by Reid, the liver weighed, in 43 82, between 48 and 58 ounces in the adult male; and in 17 cases between 40 and 50 ounces in the adult female. It is generally estim equal to about 1-36th of the weight of the whole body; but in the in early life, its proportionate weight is greater.

The specific gravity of the liver is between 1·05 and 1·06: in fatty d this is reduced to 1·03, or even less.

The liver is divided into two unequal lobes, a right and a le the under and posterior surfaces of the right lobe are three lobes or lobules, named the lobe of Spigelius, the caudate or t and the square lobe.

The **right** and **left lobes** are separated from each other on surface by the umbilical fissure (fig. 539 *u.f.*), and on the poster by its prolongation the fissure for the ductus venosus (*f.* front, their partial limit is the interlobar notch, but on t surface of the liver there is no other indication of a separatio them than the line of attachment of the fold of peritoneum t broad ligament. The right lobe is much larger and thicker left, which is very variable in extent and ordinarily constitutes one-fifth or one-sixth of the entire gland.

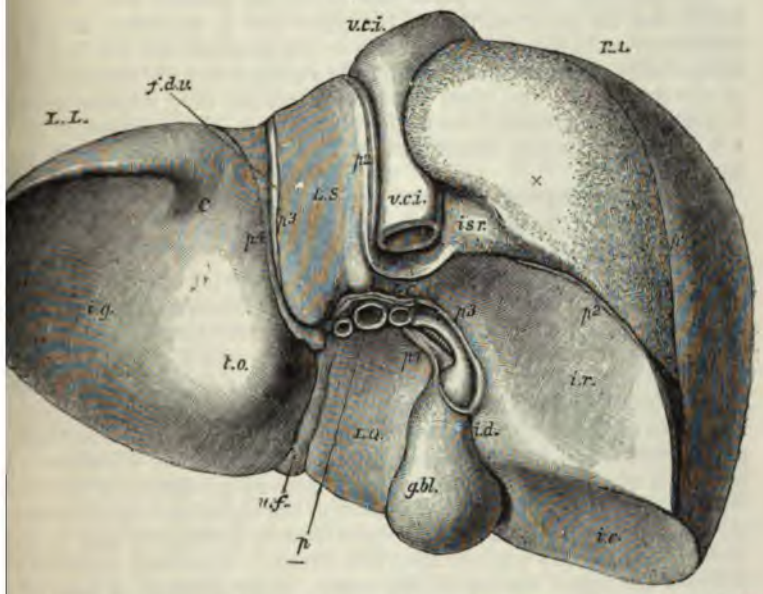
The liver is usually described as having an upper convex and an un surface which join another at the circumference of the organ; the l described as thick and rounded behind and on the right, but sharp a front and on the left. This description applies however, only to the is usually examined, viz.: in the soft condition, and after removal fro But it has been shown by His that if the organ be carefully hardene considerable part of its surface (comprehending not only what was described as the posterior border, but also portions of what have hi reckoned as belonging to the under surface, viz. a part of the left the whole of the Spigelian lobe), looks altogether backwards, and ma

re correctly described as forming a third or posterior surface. This mode
cription of the surfaces will therefore be followed here.

The upper surface of the organ is convex, smooth, and covered with
oneum. It is marked off into a right portion, large and convex,
a left portion, smaller and flatter, by the line of attachment of the
d ligament. It is exactly moulded to the under surface of the dia-
gm, and in specimens hardened *in situ* exhibits on the left portion a
ow impression corresponding to the situation of the heart.

The under surface is concave and uneven. It is invested with peri-
eum everywhere except where the gall-bladder (*g.bl.*) is adherent to
nd at the portal fissure (*p*) where the fold of peritoneum termed the

Fig. 539.



. 539.—THE LIVER OF A YOUNG SUBJECT, SKETCHED FROM BELOW AND BEHIND. (The
Irawing has been made by Mr. Wesley from a cast prepared under the direction of
Prof. His of Leipzig.) ½

R.L., right lobe; L.L., left lobe; L.S., lobe of Spigelius; L.C., caudate lobe; L.Q.,
adrate lobe; *p*, portal fissure; *u.f.*, umbilical fissure; *f.d.v.*, fissure of the ductus
nosus; *g.bl.*, gall-bladder; *v.c.i.*, vena cava inferior; *i.g.*, impression on the under sur-
e of the left lobe corresponding to the stomach; *c*, position of the cardia; *t.o.*, projec-
n of the posterior surface of the left lobe against the lesser omentum (tuber omentale, His);
., impressio colica; *i.r.*, impressio renalis; *i.sr.*, impressio supra-renalis; p^1, p^2, p^3, p^4,
es of reflection of the peritoneum; ×, surface of the liver uncovered by peritoneum.

sser omentum comes off, which encloses the blood-vessels and ducts of
e viscus, and passes to the smaller curvature of the stomach. The
nder surface of the left lobe (*i.g.*) is moulded over the subjacent cardiac
rt of the stomach, and over that part of the anterior surface of the
omach which is next to the lesser curvature. Its free margin is sharp,

curving round and subsiding posteriorly and mesially. The surface is limited in its anterior part by the umbilical fissure, but in its posterior part it slopes gradually into the portion of the lobe which appears on the posterior surface.

The under surface of the right lobe may be regarded as divided by the fossa which lodges the gall-bladder (*fossa seu impressio vesicalis*) into two unequal portions. Of these the lateral is by far the larger, and is mainly occupied by two large shallow concave impressions, one situated anteriorly being produced by the hepatic flexure of the colon (*impressio colica, i. c.*), the other and posterior one being caused by the right kidney (*impressio renalis, i. r.*) These two impressions are separated from one another by a low ridge. At the mesial border of the renal impression is a third narrow and but slightly marked impression corresponding to the descending part of the duodenum (*impressio duodenalis, i. d.*)

The mesial of the two parts into which the fossa of the gall-bladder subdivides the under surface of the right lobe is somewhat oblong and quadrangular in shape, and is known as the *quadrate lobe* (L. Q.). It is immediately over the pyloric end of the stomach and the commencement of the duodenum, and when these are distended they impress upon the surface of the quadrate lobe a slight concavity. It is bounded on the left by the umbilical fissure and behind by the transverse or portal fissure.

The **posterior surface** of the liver, which is deeply concave opposite the convexity of the vertebral column, comprehends :—1. a portion of the left lobe which lies immediately in front of the cardia, and abuts against the anterior wall of the omental sac. That part (*c*) which is in contact with the cardia is concave, but the remainder forms a considerable protuberance (*t. o.*) projecting over the lesser curvature of the stomach. This posterior surface of the left lobe passes with a gradual slope into the under surface. 2. The *Spigelian lobe* (*lobulus Spigelii*, L. S.) and the *caudate lobe* (L. C.). The latter is a narrow ridge prolonging the Spigelian lobe towards the under surface of the right lobe. It runs behind the portal fissure, and lies immediately over the foramen of Winslow. The Spigelian lobe is separated from the left lobe by the fissure of the ductus venosus, and from the posterior surface of the right lobe by the fossa for the vena cava. Its free surface looks directly backwards, and is nearly vertical and slightly concave from side to side. Superiorly it slopes over towards the upper surface of the organ, whilst inferiorly a part of the lobe overhangs part of the transverse fissure and projects against the posterior wall of the omental sac. The Spigelian lobe is opposite the tenth and eleventh dorsal vertebræ. It rests against the crura of the diaphragm, especially the right crus, and behind the upper left hand corner the lower end of the œsophagus passes obliquely into the cardia. Lower down behind the left border is the end of the thoracic aorta separated however from the liver by the diaphragm. (3). A strip of the right lobe 2½ to 3 inches broad ; convex for the most part except for a small depression at its lower and mesial corner which receives the right supra-renal capsule (*impressio supra-renalis, i.sr.*) In consequence of the separation of the layers of the coronary ligament this surface of the right lobe (fig. 539, ×) is not covered by peritoneum except at its right extremity. It rests against the ascending part of the diaphragm, and superiorly passes gradually into the upper surface. Inferiorly it is separated by a sharp margin from the renal impression of

der surface. This margin is sloped obliquely downwards and out- following the line of the 11th or 12th rib. The mesial border projects over the vena cava.

transverse or *portal fissure* (fig. 539, *p.*) is the most important, it is here that the great vessels and nerves enter, and the duct passes out. It lies transversely between the quadrate and ian lobes, and meets the longitudinal fissure nearly at right

longitudinal fissure, between the right and the left lobes, is divided wo parts by its junction with the transverse fissure. The anterior (*u. f.*), named the *umbilical fissure*, contains the umbilical vein in tus, and the remnant of that vein in the adult, which then con- es the round ligament. It lies between the square and the left lobe liver, the substance of which often forms a bridge (*pons hepatis*) the fissure, so as to convert it partially or completely into a canal. posterior part (*f. d. v.*) is named the *fissure of the ductus venosus*; situated between the lobe of Spigelius and the left lobe, and lodges tus venosus in the fœtus, and in the adult a slender cord or liga- ; into which that vein is converted.

fissure or *fossa of the vena cava* (*v. c. i.*) is situated at the back of iver, between the Spigelian lobe and the right lobe, and is separated the transverse fissure by the caudate lobe. It is at the bottom of fossa that the blood leaves the liver by the hepatic veins, which here in the vena cava. As in the case of the umbilical fissure, the ance of the liver in some cases unites around the vena cava, and es that vessel in a canal.

e transverse and umbilical fissures are on the under surface of the ; the fissure of the ductus venosus and that for the vena cava are e posterior surface.

gaments.—The ligaments of the liver are, with one exception, only ctions of serous membrane. Thus the name *coronary ligament* is given e reflection of peritoneum around the somewhat triangular portion of posterior surface of the liver (fig. 539, ×), which is here immediately rent to the diaphragm. These reflections are continued at either end a short fold—the *right and left lateral ligaments*, of which the left is the er and more distinct, the right being sometimes scarcely perceptible uthers). Another of these so-called ligaments is the *broad, falciform, uspensory ligament*, a wide thin membrane, formed of two covering rs of peritoneum continuous behind with the corresponding layers of coronary ligaments. By one of its margins it is connected with the er surface of the diaphragm, and with the sheath of the right rectus cle of the abdomen as low as the umbilicus; by another it is attached g the convex surface of the liver, from the posterior border to the ch in the anterior border: the remaining margin is free, and contains ween its layers the *round ligament*, a dense fibrous cord, the remnant he umbilical vein of the fœtus, which ascends from the umbilicus in the lower edge of the broad ligament, and enters the longitudinal re on the under surface.

osition with regard to the abdominal and thoracic parietes.—upying the right hypochondriac region, and extending obliquely ards across the epigastric region into a part of the left hypo- drium, the liver is accurately adapted to the vault of the diaphragm e, and is covered, to a small extent in front, in the subcostal

angle, by the abdominal wall. At least an inch of the left lobe is to the right of the middle line. The right lobe reaches higher beneath the ribs than the left, corresponding thus with the elevated position of the diaphragm on the right side. The liver is separated by the diaphragm from the concave base of the right lung, the thin margin of which descends so as to intervene between the surface of the body, and the solid mass of the liver.

The convex surface is protected, on the right, by the 7th to the 11th ribs, and in front by the cartilages of the 6th, 7th, 8th, and 9th ribs, and by the ensiform process—the diaphragm, of course, being interposed. The situation of the liver is modified by the position of the body, and also by the movements of respiration; thus, in the upright or sitting posture, it descends to just below the lateral margin of the thorax; but in the recumbent position ascends an inch or an inch and a half higher up, and is entirely covered by the ribs, except a small portion opposite the subcostal angle. During a deep inspiration, the liver also descends below the ribs even in the recumbent posture, and in expiration retires upwards behind them. In females it is often permanently forced downwards below the costal cartilages, owing to the use of tight stays; sometimes it reaches nearly as low as the crest of the ilium; and, in many such cases, its convex surface is indented from the pressure of the ribs.

Vessels and Nerves.—The two vessels by which the liver is supplied with blood are the hepatic artery and the portal vein. The **hepatic**

Fig. 540.

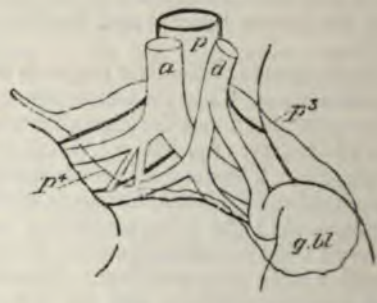


Fig. 540.—Sketch of a portion of the under surface of the liver, showing the arrangement of the vessels in the portal fissure. (G. D. Thane).

a, hepatic artery; *p*, portal vein; *d*, bile duct; *g.bl.*, gall-bladder; p^3, p^4, as in fig. 538.

artery (fig. 540, *a*), a branch of the cœliac axis, is small in comparison with the organ to which it is distributed. It enters the transverse fissure, and there divides into a right and left branch, for the two principal lobes.

By far the greater part of the blood which passes through the liver,—and in this respect it differs from all other organs of the human body,—is conveyed to it by a large vein, the **portal vein** or **vena porta** (fig. 540, *p*). This vein is formed by the union of the veins of the stomach, intestines, pancreas and spleen. It enters the transverse fissure, or *porta hepatis*, and, like the hepatic artery, there divides into two principal branches.

The hepatic artery and portal vein, lying in company with the bile-
ct, ascend to the liver between the layers of the gastro-hepatic omen-
m, in front of the foramen of Winslow, and thus reach the transverse
sure. In this course the bile-duct is to the right, the hepatic artery
the left, and the large portal vein behind the other two. They are
companied by numerous lymphatic vessels and nerves. The branches
the three vessels accompany one another in their course through
e liver nearly to their termination; and are surrounded for some
stance by an areolar investment, the so-called capsule of Glisson,
hich is prolonged into the interior of the organ.

The **hepatic veins**, which convey the blood away from the liver,
rsue through its substance an entirely different course from the other
ssels, and pass out at its posterior border, where, at the bottom of the
ssa already described, they end by two or three principal branches,
sides a number of smaller ones, in the vena cava inferior.

The **lymphatics** of the liver, large and numerous, form a deep and
superficial set. Their mode of origin and their course will be after-
rds described.

The **nerves** are derived partly from the cœliac plexus, and partly
om the pneumogastric nerves, especially from the left pneumogastric.
ey enter the liver supported by the hepatic artery and its branches;
ng with which they may be traced a considerable way in the portal
nals, but the manner of their ultimate distribution is not known.

Excretory Apparatus.—The excretory apparatus of the liver
nsists of the hepatic duct, the cystic duct, the gall-bladder, and the
mmon bile-duct.

The **hepatic** duct, formed by the union of a right and left branch,
hich issue from the bottom of the transverse fissure and unite at a
ry obtuse angle, descends to the right, within the gastro-hepatic
entum, in front of the vena portæ, and with the hepatic artery to
left. Its diameter is about two lines, and its length nearly two
ches. At its lower end it meets with the cystic duct, descending from
e gall-bladder; and the two ducts uniting together at an acute angle,
m the common bile-duct.

The **gall-bladder** (fig. 549, *g. bl*), is a pear-shaped membranous sac,
or 4 inches long, about an inch and a half across its widest part, and
pable of containing from 8 to 12 fluid-drachms. It is lodged obliquely
the fossa before mentioned on the under surface of the right lobe,
th its large end or *fundus*, which projects beyond the anterior border
the liver, directed forwards, downwards, and to the right, whilst its
k is inclined in the opposite direction. Its upper surface is attached
the liver by areolar tissue. Its under surface and fundus are covered
the peritoneum, which is reflected over them from the surface of
liver. In rare cases the peritoneum completely surrounds the
l-bladder, which is then suspended by a sort of mesentery from
under surface of the liver. The fundus touches the abdominal
letes immediately beneath the margin of the thorax, opposite the
of the tenth costal cartilage. The gall-bladder rests below on the
mmencement of the transverse colon; and, farther back, it is in con-
t with the duodenum, and sometimes with the pyloric extremity of
stomach. The *neck*, gradually narrowing, is curved like the letter S,
l then, becoming much constricted, and changing its general direction
ogether, it bends downwards and terminates in the cystic duct.

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Fig. 540.

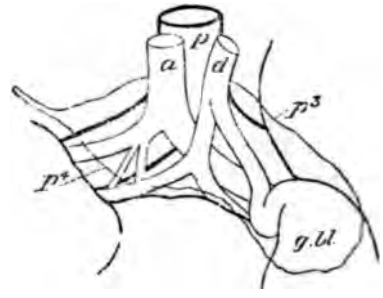

Fig. 540.—SKETCH OF A PORTION OF THE UNDER SURFACE OF THE LIVER, SH ARRANGEMENT OF THE VESSELS IN THE PORTAL FISSURE. (G. D. Th

a, hepatic artery; *p*, portal vein; *d*, bile duct; *g.bl.*, gall-bladder; p^3, p^4, a

artery (fig. 540, *a*), a branch of the cœliac axis, is small in c with the organ to which it is distributed. It enters the fissure, and there divides into a right and left branch, for the cipal lobes.

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The hepatic artery and portal vein, lying in company with the bile-duct, ascend to the liver between the layers of the gastro-hepatic omentum, in front of the foramen of Winslow, and thus reach the transverse fissure. In this course the bile-duct is to the right, the hepatic artery to the left, and the large portal vein behind the other two. They are accompanied by numerous lymphatic vessels and nerves. The branches of the three vessels accompany one another in their course through the liver nearly to their termination; and are surrounded for some distance by an areolar investment, the so-called capsule of Glisson, which is prolonged into the interior of the organ.

The **hepatic veins**, which convey the blood away from the liver, pursue through its substance an entirely different course from the other vessels, and pass out at its posterior border, where, at the bottom of the fossa already described, they end by two or three principal branches, besides a number of smaller ones, in the vena cava inferior.

The **lymphatics** of the liver, large and numerous, form a deep and a superficial set. Their mode of origin and their course will be afterwards described.

The **nerves** are derived partly from the cœliac plexus, and partly from the pneumogastric nerves, especially from the left pneumogastric. They enter the liver supported by the hepatic artery and its branches; along with which they may be traced a considerable way in the portal canals, but the manner of their ultimate distribution is not known.

Excretory Apparatus.—The excretory apparatus of the liver consists of the hepatic duct, the cystic duct, the gall-bladder, and the common bile-duct.

The **hepatic** duct, formed by the union of a right and left branch, which issue from the bottom of the transverse fissure and unite at a very obtuse angle, descends to the right, within the gastro-hepatic omentum, in front of the vena portæ, and with the hepatic artery to its left. Its diameter is about two lines, and its length nearly two inches. At its lower end it meets with the cystic duct, descending from the gall-bladder; and the two ducts uniting together at an acute angle, form the common bile-duct.

The **gall-bladder** (fig. 549, *g. bl*), is a pear-shaped membranous sac, 3 or 4 inches long, about an inch and a half across its widest part, and capable of containing from 8 to 12 fluid-drachms. It is lodged obliquely in the fossa before mentioned on the under surface of the right lobe, with its large end or *fundus*, which projects beyond the anterior border of the liver, directed forwards, downwards, and to the right, whilst its *neck* is inclined in the opposite direction. Its upper surface is attached to the liver by areolar tissue. Its under surface and fundus are covered by the peritoneum, which is reflected over them from the surface of the liver. In rare cases the peritoneum completely surrounds the gall-bladder, which is then suspended by a sort of mesentery from the under surface of the liver. The fundus touches the abdominal parietes immediately beneath the margin of the thorax, opposite the tip of the tenth costal cartilage. The gall-bladder rests below on the commencement of the transverse colon; and, farther back, it is in contact with the duodenum, and sometimes with the pyloric extremity of the stomach. The *neck*, gradually narrowing, is curved like the letter S, and then, becoming much constricted, and changing its general direction altogether, it bends downwards and terminates in the cystic duct.

the course of the hepatic duct, between the layers of
omentum, in front of the vena portæ, and to the r
artery. Passing behind the first part of the duode
descending portion and continues downwards on the
aspect of that part of the intestine, covered by or in
of the pancreas, and for a short distance in contact
of the pancreatic duct. Together with that duct, it
muscular wall of the duodenum, and, after running
quarters of an inch between its coats, and forming a
the mucous membrane, it becomes somewhat constric
common orifice with the pancreatic duct on the inner s
tine, near the junction of the second and third portion
and three or four inches beyond the pylorus, as alread

Varieties.—The liver is not subject to great or freque
ordinary form and relations. Sometimes it retains the thick
it presents in the fœtus; and it has occasionally been found
into lobes. On the other hand, Sœmmerring has recorded
adult liver was divided into twelve lobes; and similar case
(resembling that of some animals) have been now and the
A detached portion, forming a sort of *accessory* liver, i
appended to the left extremity of the gland by a fold of p
blood-vessels.

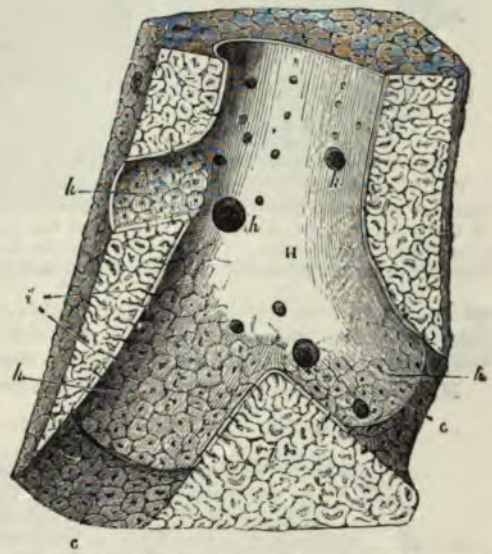
The gall-bladder is occasionally wanting, in which case
much dilated within the liver, or in some part of its co
gall-bladder is irregular in form, or is constricted across
much more rarely, it is partially divided in a longitudi
communications by means of small ducts (named hepato-
the liver to the gall-bladder, exist regularly in various an
sometimes found, as an unusual formation, in the human su

The right and left divisions of the hepatic duct sometim
for some distance within the gastro-hepatic omentum. Las
duct not unfrequently opens separately from the panc
duodenum.

ated a strong sheath of areolar tissue which surrounds the branches portal vein, hepatic artery, and hepatic duct, as they ramify in bstance of the liver, but which becomes more delicate as it passes the smaller vascular branches.

patic lobules.—The proper substance of the liver, which has a ed aspect when closely observed, is compact, but not very firm. easily cut or lacerated, and is not unfrequently ruptured during life accidents in which other parts of the body have escaped injury. n the substance of the liver is torn, the broken surface is not th, but coarsely granular, the liver being composed of a multitude mall lobules (fig. 541), which vary from $\frac{1}{24}$th to $\frac{1}{12}$th of an inch in meter (1—2 millimetres).

Fig. 541.



541.—SECTION OF A TION OF LIVER PASSING NGITUDINALLY THROUGH CONSIDERABLE HEPATIC IN, FROM THE PIG (after rman). ABOUT 5 DIA-TERS.

hepatic venous trunk, ast which the sides of the les are applied; *h*, *h*, *h*, e sublobular hepatic veins, which the bases of the les rest, and through the s of which they are seen olygonal figures; *i*, mouth the intralobular veins, ing into the sublobular s; *i'*, intralobular veins n passing up the centre me divided lobules; *c*, *c*, n of the hepatic venous l, with the polygonal bases e lobules.

These lobules in some animals, as in the pig and camel, are comely isolated one from another by areolar tissue continuous with the ous coat of the liver, and with the capsule of Glisson; but in the man subject, and in most animals, although very distinguishable, they not completely insulated, being confluent in a part of their extent.

The lobules of the liver have, throughout its substance, in general polyhedral form of irregularly compressed spheroids; but on the face they are flattened and angular. They are all compactly arged around the sides of branches (*sublobular*) of the hepatic veins 541), each lobule resting by a smooth surface or *base*, upon the , and being connected with it by a small venous trunklet (*intralar*), which begins in the centre of the lobule, and passes out from middle of its base, to end in the larger subjacent vessel. If one of sublobular veins be opened (as in the figure), the bases of the lobules be seen through the coats of the vein, which are here very thin, enting a tesselated appearance, each little polygonal space repreng the base of a lobule, and having in its centre a small spot, h is the mouth of the *intralobular* vein (*i*).

Each lobule consists of a mass of cells penetrated from the cir
ference to the centre by a close network of blood-capillaries, as

Fig. 542.

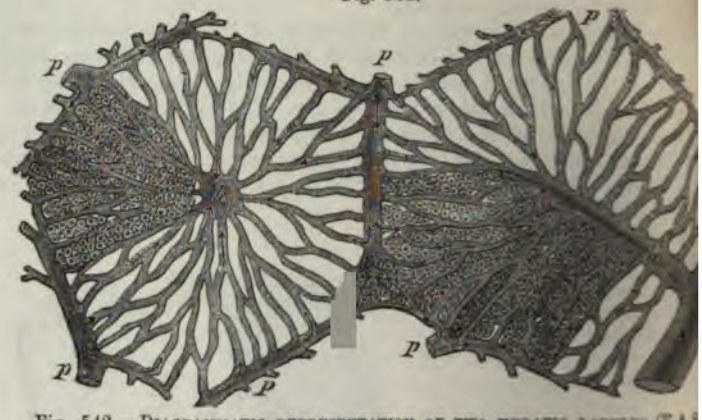


Fig. 542.—Diagrammatic representation of two hepatic lobules (E.A.S
The left-hand lobule is represented with the intralobular vein cut across; in the
hand one the section takes the course of the intralobular vein. P, interlobular br
of the portal vein; H, intralobular branches of the hepatic veins; S, sublobular
C, capillaries of the lobules. The arrows indicate the direction of the course of the
The liver-cells are only represented in one part of each lobule.

as by the minute capillary commencements of the bile-ducts, with
intervention of little other tissue. For the sake of clearness, the
position of the vessels of the liver may be considered first.

Blood-vessels.—The portal vein and hepatic artery, accompani

Fig. 543.

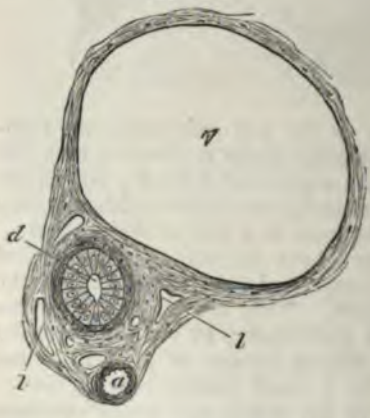


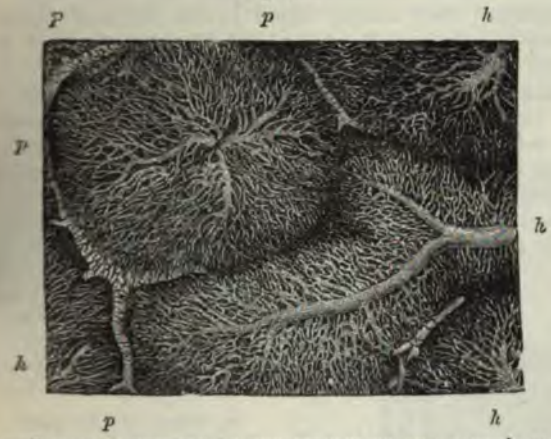
Fig. 543.—Section of a portal
(E.A.S.).
a, branch of hepatic artery; *v*, br
portal vein; *d*, bile-duct; *l*, lym
in the areolar tissue of Glisson's
which encloses the vessels.

the emerging biliary ducts,
the liver at the transverse fi
Within the liver the branch
these three vessels lie togeth
certain canals, called *portal ca*
which are tubular passages for
in the substance of the gland,
mencing at the transverse fis
and branching upwards and
wards from that part in all di
tions. Each portal canal (even
smallest) contains one princ
branch of the vena portæ, of the hepatic artery, and of the biliary d
(fig. 543); the whole being invested by connective tissue, within wh
run lymphatic vessels.

The **portal vein** subdivides into branches which ramify between t
lobules, anastomosing freely around them, and are named *interlobular*
peripheral veins (fig. 542, P). The branches of these pass into the lobu

circumference and end in the capillary network, from which
lobular or central veins take origin. Within the portal canals
ches of the portal veins receive small veins which are returning
stributed by branches of the hepatic artery.

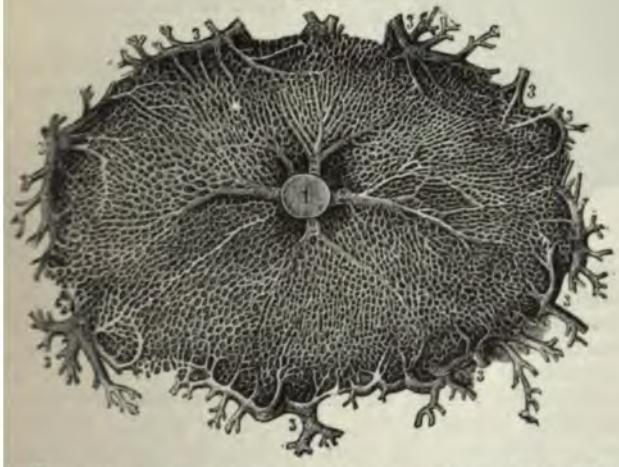
Fig. 544.



4.—CAPILLARY NETWORK OF THE LOBULES OF THE RABBIT'S LIVER (from Kölliker). ABOUT 40 DIAMETERS.

re is taken from a very successful injection of the hepatic veins made by
it shows nearly the whole of two lobules, and parts of three others: *p*, portal
nning in the interlobular spaces; *h*, hepatic veins radiating from the centre
les.

Fig. 545.



.—CROSS SECTION OF A LOBULE OF THE HUMAN LIVER, IN WHICH THE CAPILLARY
RK BETWEEN THE PORTAL AND HEPATIC VEINS HAS BEEN FULLY INJECTED
Sappey). 60 DIAMETERS.

tion of the intralobular or central vein; 2, its smaller branches collecting blood
e capillary network; 3, interlobular or peripheric branches of the vena portæ
eir smaller ramifications passing inwards towards the capillary network in the
e of the lobule.

The **hepatic artery** terminates in three sets of branches, vaginal, capsular, and interlobular. The *vaginal* branches ramif the portal canals, supplying the walls of the ducts and vessels, accompanying connective tissue. The *capsular* branches appea surface of the liver spread out on the fibrous coat, accompanied veins. The *interlobular* branches accompany the interlobular v are much smaller; they supply blood to the walls of these accompanying bile-ducts; it is doubtful if they transmit a directly to the capillary network of the lobules.

The **capillary network** of the lobules is very close, so that c the interval between two vessels is not greater than the diamet or two liver cells (fig. 542). Moreover the vessels are comparativ ($\frac{1}{2500}$th of an inch), and in specimens in which they have been fi transparent injection, can be seen, not only to pass in a radiating as before described, between the intra- and inter-lobular veins, in the human subject to be continued from one lobule to anothe

Fig. 546.

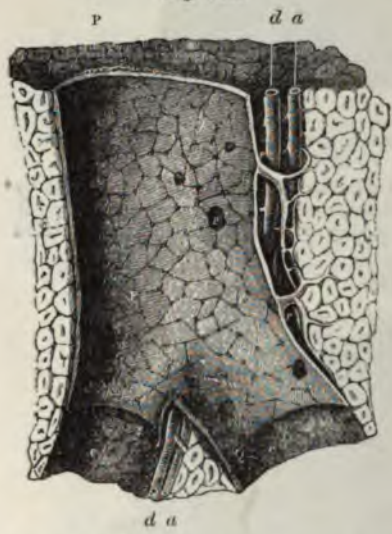


Fig. 546.—LONGITUDINAL SEC PORTAL CANAL, CONTAINING VEIN, HEPATIC ARTERY, AN DUCT, FROM THE PIG (after ABOUT 5 DIAMETERS.

P, branch of vena portæ, a portal canal, formed among patic lobules of the liver; p branches of portal vein, giving ones named interlobular vei are also seen within the la vein numerous orifices of in veins arising directly from it; artery; *d*, biliary duct; at venous wall has been partially

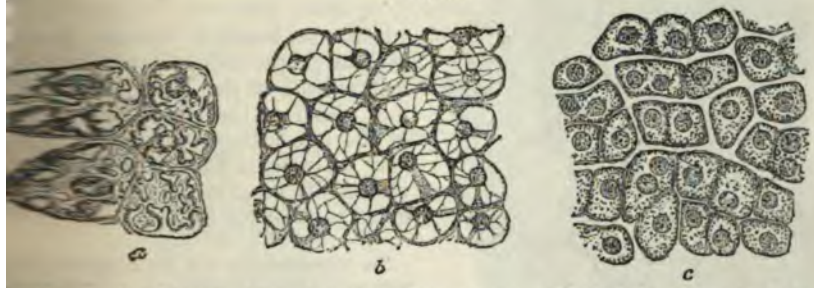
The capillaries are acco by a very small amount of tive tissue, containing and stellate cells. This occurs more abundantly a centre of the lobule aro intralobular vein; and be and in that accompany interlobular veins, there are numerous granular connective tissue

The **hepatic veins** commence in the centre of each lobule convergence of its capillaries into the single independent *intralo central vein* (figs. 542, H; 544, *h*; and 545, 1), as already stated. minute intralobular veins open at once into the sides of the s *sublobular* veins (fig. 542, S), which are of various sizes, and join larger and larger vessels, ending at length in hepatic venous which receive no intralobular veins. Lastly, these venous trunk verging towards the posterior border of the liver, and receiving course other sublobular veins, terminate in the vena cava inf already described. In this course the hepatic veins and their sm ramifications are unaccompanied by any but lymphatic vessels. coats are thin; the sublobular branches adhere closely to the lobu even the larger trunks have but a slight areolar investment com

m to the substance of the liver. Hence the divided ends of these s are seen upon a section of the liver as simple open orifices, the wall of the vein being surrounded closely by the solid substance of gland.

he hepatic cells.—The interstices between the blood-vessels are, efore said, almost entirely filled by the hepatic cells. These are of mpressed spheroidal or polyhedral form, having a mean diameter of m $\frac{1}{1050}$th to $\frac{1}{540}$th of an inch. They possess no cell membrane. Their stance appears granular and of a faint yellowish tinge, and they tain each a clear round nucleus, with intra-nuclear network and one or

Fig. 547.



g. 547.—Hepatic cells from the liver of a dog (Heidenhain), 14 hours after a full meal.

a, with glycogenic deposit; *b* and *c*, after its solution. In *c* the network of protoplasm hich remains is finer than in *b*, and imparts a somewhat granular appearance to the ells. The external layer of the protoplasm contains no glycogen.

wo nucleoli. Not unfrequently two nuclei are to be found in a cell. In many cases especially with a fatty diet, the cells are found to have large or small fat-globules in their interior; this fatty deposit is much more abundant in the cells which are near the periphery than in those near the centre of the lobule. When isolated in the fresh condition they are said to exhibit slow changes of form. The liver-cells are packed between and around the vessels, and in sections made at right angles to the intralobular veins, appear as if radiating from the centre of the lobules towards their circumference. They form a continuous network, or spongework, the more obvious openings in which are the spaces occupied by the blood-capillaries. The walls of the latter are not everywhere in contact with the liver cells, but are separated from them in parts by a cleft-like lymphatic space which is only imperfectly marked off by the flattened and stellate connective tissue cells before mentioned (p. 246).

The hepatic cells frequently contain glycogen especially after a heavy meal of starchy matters. It occurs in globules or in irregular amorphous masses within them (Heidenhain), and when abundant reduces the protoplasm of the cell to the condition of an open network, which becomes very distinct after solution of the glycogen (fig. 547). When these masses of glycogen are not present the protoplasm exhibits after hardening a finely reticulated appearance (Klein, Langley). (See fig. 45.)

Commencement of the ducts.—When a thin section of the hardened tissue is examined under a high power of the microscope, minute apertures

may occasionally be observed between the opposed sides of
liver-cells. These are the sections of fine intercellular passag
canaliculi) which form a close network (fig. 548) between and
the individual cells, much finer and closer than the blood-capil
work, from the branches of which they run apart. These

Fig. 548.

Fig. 548.—Section of rabb
with the intercellular
of bile-canaliculi injecte
magnified (Hering).

Two or three layers of cell
sented; *b*, *b*, blood capillaries

which are bounded by
delicate proper wall, are
mencements of the bili
into which at the circu
of the lobule they open
may be injected from t
of the bile duct, at leas
outer parts of the lobule.

To demonstrate the int
network throughout the wh
of the lobules, Chrzonszcze
ployed a method of natural
He introduced a saturate
solution of pure sulph-ind
soda, in repeated doses, int
culation of dogs and suckin
the jugular vein; and in an hour and a half afterwards the animals w
and the blood-vessels either washed out with chloride of potassium i
by the portal vein, or were injected with gelatine and carmine. In
prepared in this way the fine network of bile-ducts throughout each
filled with blue, while the intervening cells remain free from colour.
the animals sooner after the injection, the blue colouring matter
within the hepatic cells, thus demonstrating that it was through th
that the canals were filled.

From the observations of Pflüger and of Kupffer it would appea
relation between the hepatic cells and the bile-canaliculi is even mor
than has been generally supposed. For both by the methods of artifi
natural injection, they have demonstrated the existence of vacuoles
cells communicating by exceedingly minute intracellular channels
adjoining bile-canaliculi (see fig. 549).

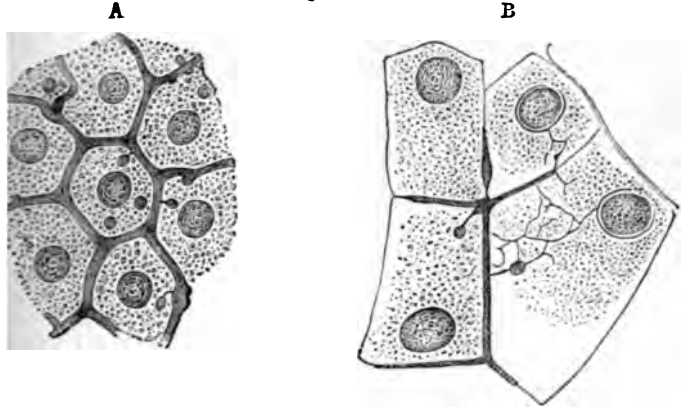
In the lower vertebrates and in the earlier stages of development in
mammals the liver is a tubular gland, composed of anastomosing tu
narrow lumina (biliary canaliculi), and directly continuous with the
all animals the bile-canaliculi are separated by at least a portion of
the nearest blood capillaries.

Structure of the ducts.—The minute ramifications be
lobules have walls composed of fibrillar connective tissue, wit
is a basement membrane, and a lining of short columnar e
According to Heidenhain they also possess both longitudi
circularly disposed muscular cells in their wall. As they
the lobules, the columnar epithelium becomes shorter and f
tube at the same time branching both laterally and termi

ng much reduced in size so that only a very small lumen is left. sement membrane is no longer complete, and the intercellular ssages open directly into the minute ducts, the hepatic cells g against the flattened epithelium of the latter.

ie portal canals, where they are somewhat larger, the ducts pre- merous openings on the inner surface, which are scattered irregu- ı the larger ducts, but in the subdivisions are arranged in two dinal rows, one at each side of the vessel. These openings were ly supposed to be the orifices of mucous glands; but, while the ucts are studded with true mucous glands of lobulated form and inute orifices, the openings now referred to belong to saccular and · recesses, which are often branched and anastomosing, and may t all over with cæcal projections (Theile). The larger bile-ducts reolar coats, containing abundant elastic tissue, and a certain ; of plain muscular tissue disposed both longitudinally and ·ly. They are lined with columnar epithelium.

Fig. 549.



549.—SKETCHES ILLUSTRATING THE MODE OF COMMENCEMENT OF THE BILE-CANALICULI WITHIN THE LIVER-CELLS (Heidenhain after Kupffer).

naliculi of the rabbit's liver, artificially injected from the hepatic duct, with due solution. The intercellular canaliculi are seen to give off minute twigs, which le into the liver-cells, and there terminate in vacuole-like enlargements.

rom a frog's liver naturally injected with sulph-indigotate of soda. A similar nce is obtained, but the communicating twigs are ramified.

ie duplicature of peritoneum forming the left lateral ligament of the liver, o in the two fibrous bands which sometimes bridge over the fossa for the ava and the fissure of the umbilical vein, there have been found biliary f considerable size which are not surrounded with lobules. These *aberrant* s they are called, were described by Ferrein and afterwards by Kiernan; astomose together in form of a network, and are accompanied by branches vena portæ, hepatic artery, and hepatic vein. They represent portions of substance which were present at an early period of development but bsequently become atrophied.

phatics of the liver.—Lymphatics are seen in the prolongations of 's capsule between the lobules (*interlobular lymphatics*), where they any the blood-vessels, and in some cases surround and enclose them. They e from the lymphatic spaces around the capillaries of the lobules (p. 247). nite into larger vessels *which run along* the portal canals and emerge at

tive tissue coat, of considerable strength. This consists mai
dense shining white fibres, which interlace in all directions. In
these are plain muscular fibres, which have principally a longit
but some run transversely. This coat forms the framework o
supports the larger blood-vessels and lymphatics. The nerves f
plexus within it; partly also immediately beneath the serous co

The *mucous membrane*, which after death is generally strongly ti
elevated upon its inner surface into very numerous small ridge
together into meshes, leave between them depressions of differ
various polygonal forms. This gives the interior of the gall-bl
aspect, similar to what is seen on a smaller scale in the ve
These alveolar intervals become smaller towards the fundus
gall-bladder; and at the bottom of the larger ones, other mi
which may be seen with a simple lens, lead into numerous
The whole of the mucous membrane is covered by columnar e
secretes an abundance of viscid mucus. The blood-vessels form
near the surface of the mucous membrane, and there is also
plexus in the mucous membrane, communicating with a ne
vessels in the serous coat.

At the places where the neck of the gall-bladder curves on
strong folds of its mucous and areolar coats projecting into the

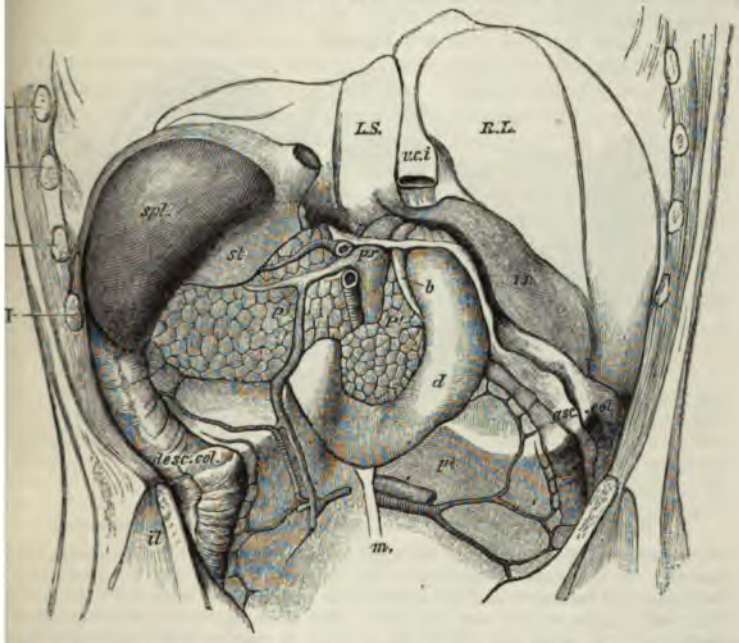
In the *cystic duct*, the mucous membrane is elevated intern
manner into a series of crescentic folds, which are arranged in
tion, and succeed closely to each other, so as to present very muc
of a continuous spiral valve. When distended, the outer surfac
pears to be indented in the situation of these folds, and dilated
intervals, so as to present an irregularly sacculated or twisted ap
structure of its wall, the cystic duct resembles the gall-bladder.

Recent Literature.—On the structure of the liver generally: *He*
Handbook, 1871; *Heidenhain*, in Hermann's Handbuch, 1880. On
bile-ducts: *Kupffer*, in Tagebl. d. 46 Versamml. d. Naturf., 1873, a
naturw. Ver. f. Schleswig-Holstein, III.; *Legros*, in Journ. de l'an
Sächs. Bericht., 1873; *Peszke*, Beiträge, &c., Dorpat, 1874; *Popoff*
LXXXI. On the terminations of the hepatic artery: *Cohnheim* u. *Litt*
LXVII. On the connective tissue of the liver: *Fleischl*, in Sächs
Kupffer, in Arch. f. mikr. Anat., XII., 1875; *Turner* (camel's li
Anat. and Physiol. XI., 1877. On the structure of the gall-bladder
Berlin, 1875. On the position and form of the liver: *His*, in Arch. f.
1878.

ıward projection following the curve of the duodenum, and from its r border another well marked protuberance rises up to reach the r curvature of the stomach, and to abut against the posterior wall of ɔmentum opposite to the similar projection on the left lobe of the (see fig. 550).

e pancreas varies considerably, in different cases, in its size and weight. It ually from 6 to 8 inches long, about 1½ inches in average breadth, and from an inch to an inch in thickness, being thicker at its head and along its upper r than elsewhere. The weight of the gland, according to Krause and Clening, is usually from 2¼ oz. to 3½ oz.; but Meckel has noted it as high as 6 oz., Sœmmerring as low as 1½ oz.

Fig. 550.



550.—VIEW OF THE ABDOMINAL VISCERA FROM BEHIND, AFTER REMOVAL OF THE NAL COLUMN AND THE WHOLE OF THE POSTERIOR WALL OF THE ABDOMEN, THE ITONEUM BEING LEFT (this and the next figure are taken from Prof. His' models). ½

pancreas; *P'*, its head; *d*, duodenum; *st*, stomach; *spl*, spleen; *R.L.*, right lobe liver; *L.S.*, Spigelian lobe; *v.c.i.*, vena cava inferior; *p.r.*, portal vein; *b*, comile duct; *i.r.*, impression for the right kidney on the posterior surface of the liver; tuation of the two kidneys is well shown by the corresponding impressions in the *asc. col.*, *desc. col.*, ascending and descending colon; *pt*, back of the peritoneum; ıe of reflection of the mesentery seen through; VIII, IX, X, XI, the corresponding *il*, ilium.

ıe pancreas has three surfaces, viz.: anterior, posterior and a narrow ior surface (His). These surfaces, like those of the liver, are ded to the adjacent organs.

ıe *anterior surface*, somewhat concave, is covered by the stomach, h rests upon it.

he *posterior surface* is attached by areolar tissue to the vena ca

the aorta, the superior mesenteric artery and vein, the commencem of the vena portæ, and the pillars of the diaphragm, all of wh parts, besides many lymphatic vessels and glands, are interposed betw it and the spine : to the left of the vertebral column it is attac similarly to the left suprarenal capsule and kidney and to the n vessels. Of the large vessels situated behind the pancreas, the supe mesenteric artery and vein are embraced by the substance of the gl the lower extremity of the head curving somewhat behind them,* as sometimes to enclose these vessels in a complete canal. They downwards and forwards, and emerge from beneath the lower border of pancreas, between it and the termination of the duodenum (fig. 551). cœliac axis is above the pancreas ; and in a groove along the poste surface and upper border of the gland are placed the splenic artery

Fig. 551.

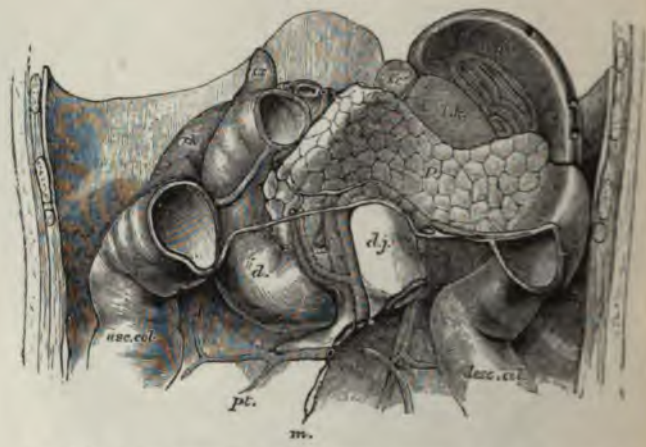


Fig. 551.—THE PANCREAS AND ADJOINING VISCERA FROM BEFORE. ½

The stomach, the greater part of the small intestines, and the transverse colon have removed. *P*, pancreas ; *d*, duodenum ; *d.j*, its junction with the jejunum ; above duodenum, and between it and the head of the pancreas are seen the bile duct, p vein, and hepatic artery ; *asc. col.*, *desc. col.*, ascending and descending colon ; spleen ; *r.k.*, *l.k.*, right and left kidneys ; *s.r.*, *s.r'*, right and left suprarenal cap *pt*, peritoneum at the back of the abdominal cavity ; *m*, line of reflection of the m tery ; the line of reflection of the transverse mesocolon is seen along the lower edge pancreas and crossing the duodenum.

vein, the vein pursuing a straight, and the artery a tortuous course, both supplying numerous branches to the pancreas, the narrow extre of which is attached to the inner or anterior surface of the spleen.

The common bile duct passes down behind the head of the pan (fig. 550, *b*), and is generally received into a groove or canal in its subst

The *inferior surface* is very narrow. The border which separat from the anterior surface is turned towards the root of the meso while the inferior surface itself rests at one end on the junctio duodenum and jejunum ; at the other or left end on the extremi

* This part of the gland is sometimes marked off from the rest, and is then name *lesser pancreas.*

ansverse colon, and between these points is turned towards the l mass of the intestinal convolutions. This part of the inferior s has a special covering of peritoneum derived from the lower f the mesocolon.

principal excretory duct called the **pancreatic duct** or **canal of ung**, runs through the entire length of the gland, from left to buried completely in its substance, and placed rather nearer its than its upper border. Commencing by the union of the small derived from the groups of lobules composing the tail of the as, and receiving in succession at various angles, and from all the ducts from the body of the gland, the canal of Wirsung in- s in size as it advances towards the head of the pancreas, where, st other large branches, it is usually joined by one derived from ortion of the gland called the lesser pancreas. Curving slightly wards, the pancreatic duct then comes into contact with the left f the common bile duct, which it accompanies to the posterior part descending portion of the duodenum. Here the two ducts, placed y side, pass very obliquely through the muscular and areolar coats e intestine, and terminate, as already described, on its internal e, by a common orifice, situated at the junction of the second and portions of the duodenum, between three and four inches below the us. The pancreatic duct, with its branches, is readily distinguished n the glandular substance, by the very white appearance of its thin s walls. Its widest part, near the duodenum, is from $\frac{1}{12}$th to $\frac{1}{9}$th inch in diameter, or nearly the size of an ordinary quill. It is lined emarkably thin and smooth membrane, which near the termination duct may present a few scattered recesses.

rieties.—Sometimes the duct is double up to its point of entrance into the num; and a still further deviation from the ordinary condition is not quently observed, in which there is a *supplementary* duct, derived from the pancreas or some part of the head of the gland, opening into the duodenum listinct orifice, at a distance of an inch or more from the termination of incipal duct. It sometimes occurs that the pancreatic duct and the common uct open separately into the duodenum.

sels and Nerves.—Like the salivary glands, the pancreas receives its vessels at numerous points. Its arteries are derived from the splenic and the superior and inferior pancreatico-duodenal branches of the hepatic and ior mesenteric. Its blood is returned by the splenic and superior mesenteric . Its lymphatics terminate in the lumbar vessels and glands. The nerves e pancreas are derived from the solar plexus.

ructure.—The pancreas belongs to the class of acino-tubular ls. In its general characters it closely resembles the salivary ls, but it is somewhat looser and softer in its texture than those us, the lobes and lobules being less compactly arranged.

ne ducts are lined with a simple layer of columnar epithelium, the becoming shorter and more cubical in the smaller ducts. They ot exhibit any well-marked longitudinal striation like that met with e duct-cells of some of the salivary glands. The ultimate branches he ducts which are connected with the alveoli (intercalary), are much narrowed, and are lined with flattened cells, looking lle-shaped in optical section. The alveoli of the gland are distinctly lar, and frequently convoluted. In the inactive condition of the l, and during the earlier stages of activity, the alveoli are almost

completely occupied by the secreting cells, scarcely any lume visible. Moreover the middle of the alveolus is in many par pied by spindle-shaped cells (centro-acinar cells) which acco Langerhans are continuous with the epithelium-cells of the in ducts.

Fig. 552.

Fig. 552.—Section of the of the dog. (Klei

d, termination of a duct in t alveoli, *a* : the two zones in t cells are well seen.

The secreting cells of creas have a very chara appearance. In shape broadly columnar, in so approaching the polygo and they show very di even in the inactive con the gland, two parts o an inner granular zone lumen, and an outer cl finely striated zone next ment membrane (fig. 55

When the gland is stimulated to activity the cells at first enlarge and basement membrane ; subsequently the granules of the inner zone becc in number and aggregated near the lumen, and the outer clear zone exte the greater part of the cell (Heidenhain, Kühne and Lea).

Various observers after forcing injections into the alveoli of the pancr wards from the duct, have seen fine intercellular canaliculi, comparable of the liver, passing from the lumen of an alveolus between the secretin

Fig. 553.

Fig. 553.—An alveolus of the pancreas inject the excretory duct (Saviotti). Highly magnifi

The alveolar cells and nuclei are only faintly indicat of the duct are not represented at all. The injecti filling the central cavity of the alveolus, and passing in fine channels (represented by black reticulating tween and around the cells (after Saviotti).

The connective tissue of the gland, after formi of external investment, penetrates between its lobules conveying the blood-vessels to all part are not however everywhere equally numerous. acini are not surrounded by the capillary netw the other hand in certain parts of the interalveol collections of small cells are met with which rounded with a very close network of large convoluted capillaries. Th question look like small epithelium-cells but their meaning is entirely u The lymphatics of the pancreas have the same arrangement as in the salivar

The mode or termination of the nerves, which are almost exclusiv medullated, has not been ascertained.

Recent Literature.—*Langerhans*, Beiträge, &c., Berlin, 1869 ; Saviotti, mikr. Anat., V. 1869 ; *Latschenberger* in Wiener Sitzungsb., 65, 1872 ; *Heid* Pflüger's Arch., X. 1875 ; and Article "Absonderung," in Hermann's Handbu *Kühne u. Lea* in Heidelberg Verhandl. I. 1876 ; *G. & F. Hoggan* in Journ. 1881 (efferent lymphatics in rodents).

THE SPLEEN.

e spleen (figs. 550, 551, *spl*) is a soft highly vascular and easily isible organ, of a dark purplish grey colour. It is placed obliquely e back of the left hypochondrium, between the cardiac end of the ach, and the diaphragm, and in the line of the axilla extends the 8th to the 11th rib. It is the largest of the organs termed ess glands.

he shape of the spleen is variable, but when examined in the ordi- way after removal from the body, it usually appears either flattened oncavo-convex. But if previously hardened *in situ* it is found to ent a somewhat compressed oval shape, having three surfaces. Of se, one, the external and posterior, is large and convex, fitting against commencement of the arch of the diaphragm, and looking upwards, wards, and to the left. A second, the narrowest, is placed vertically, looks directly inwards, being applied to the outer border of the kidney; whilst the third surface, which is separated from that last ribed by a distinct vertical ridge, is larger than it, and concave. is surface is applied to the great cul-de-sac of the stomach, and is in tact also with the tail of the pancreas, and with the extremity of the of the colon (splenic flexure). Near the ridge above mentioned re is a vertical fissure in the anterior surface, at the part where the sels and nerves enter the organ (see fig. 551); this part is termed the *lus*. On either side of the hilus, the peritoneum, which covers the le of the rest of the spleen, leaves the organ, and passes, as the tro-splenic omentum, into continuity with the left border of the great ntum, attaching the spleen to the left extremity of the stomach. In e cases there is no distinct fissure at the hilus. The anterior border often slightly notched, especially towards the lower part (fig. 551). lower end of the organ is pointed, and rests on the costo-colic ament.

The spleen varies in magnitude more than any other organ in the body; and this not only in different subjects, but, as may be ascertained by percussion, in the same individual, under different conditions. On this account it is difficult or impossible to state what are its ordinary weight and dimensions: in the adult it measures generally about 5 or 5½ inches in length, 3 or 4 inches in breadth, and 1 or 1½ inch in thickness; and its usual volume, according to Krause, is from 9¾ to 15 cubic inches. After the age of forty the average weight gradually diminishes. In intermittent and some other fevers the spleen is much enlarged, reaching below the ribs, and often weighing as much as 18 or 20 lbs.

Small detached roundish nodules are occasionally found in the neighbourhood of the spleen, similar to it in substance. These are commonly named accessory or supplementary spleens (splenculi; lienculi). One or two most commonly occur, but a greater number, and even up to twenty-three, have been met with. They are small rounded masses, varying from the size of a pea to that of a walnut. They are usually situated near the lower end of the spleen, either in the gastro-splenic omentum, or in the great omentum.

STRUCTURE OF THE SPLEEN.

The spleen has two membranous investments—a serous coat derived from the peritoneum, and a special tunic. The soft substance (pulp) of the organ is supported by a reticular framework of whitish bands or *trabeculæ*.

The **serous** coat is thin, smooth, and firmly adherent to th
propria beneath. It closely invests the surface of the organ, e
the places of its reflection to the stomach and diaphragm, an
hilus.

Fig. 554.

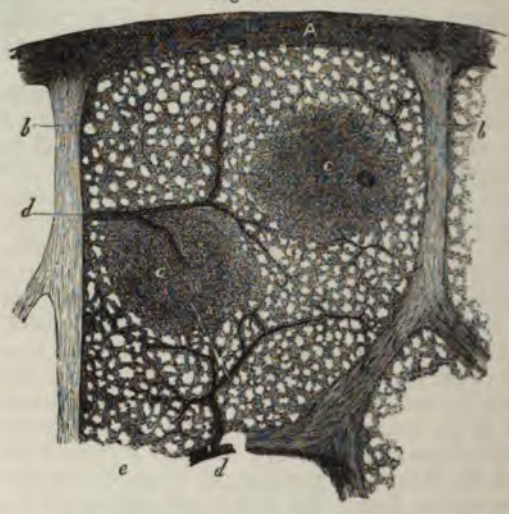


Fig. 554.—VERTICA
OF A SMALL S
PORTION OF TH
SPLEEN (from
Magnified with a

A, peritoneal a
covering ; *b*, trabe
Malpighian corpus
of which an artery
transversely, in the
tudinally ; *d*, injec
twigs ; *e*, spleen-pu

The **tunica**
(fig. 554, A),
thicker and
than the serous
whitish in col
highly elastic.
continuous with
becular structur
Along the hi
coat is reflected
interior of the spleen, in the form of large trabeculæ, s
and enclosed by which run the blood-vessels and nerves;
these are ensheathed by prolongations of the fibrous coat.

Fig. 555.

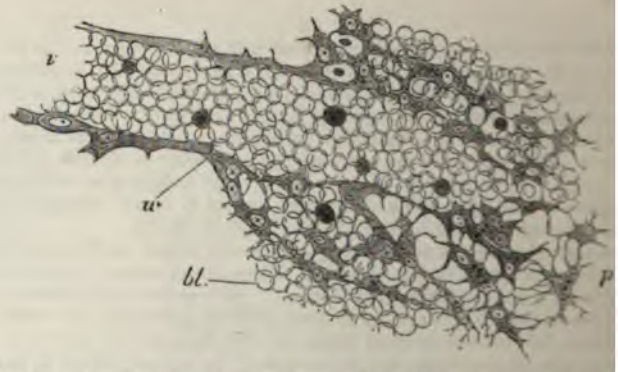


Fig. 555.—THIN SECTION OF SPLEEN-PULP, HIGHLY MAGNIFIED, SHOWING THE
ORIGIN OF A SMALL VEIN. (E.A.S.)

v, the vein, filled with blood-corpuscles, which are in continuity with others
up the interstices of the retiform tissue of the pulp. At *p* the blood-corpuscles
omitted from the figure, and the branched cells are better seen ; *w*, wall of
The shaded bodies amongst the red blood-corpuscles are pale corpuscles.

sheaths ramify with the vessels which they include, as far as th
subdivisions, and are connected with numerous trabecular

pass into the interior from the whole inner surface of the fibrous
The arrangement of the sheaths and trabeculæ may be easily
ed in the spleen of the ox by pressing and washing out the
om a section; and then they are seen to form a close reticu-
through the substance. Thus, the proper coat, the sheaths
vessels, and the trabeculæ, all of a highly elastic nature,
ute a distensible framework, which contains in its interstices
ulæ the red pulp. These fibrous structures are composed of
ced bundles of areolar tissue containing a large amount of fine
tissue, and a few plain muscular fibre-cells. In the spleen of
g, the dog, and the cat, and to a smaller extent in that of the
d sheep, there is a far more abundant admixture of muscular

pulp of the spleen is of a dark reddish-brown colour: when
d out from between the trabeculæ it resembles grumous blood, and,
at, acquires a brighter hue on exposure to the air.
en a thin section which has been treated with solution of potash
mined under the microscope the pulp is seen to be everywhere
ded by a reticulum of fine fibres, probably elastic, and continuous
the tissue of the trabeculæ. These fibres are in the natural con-
covered over and concealed by branched connective-tissue
ples, which are of various forms and sizes; in some parts little
e intercommunicating branches remaining, in other parts the cells
larger and flatter and in closer connection (fig. 555, *p*). These
cles, which may be termed the *supporting cells of the pulp*, contain
round or oval nucleus, like connective-tissue cells generally: and,
ced-out preparations of the fresh spleen substance it is not un-
on to find within them yellowish pigment granules of various sizes,
nably derived from blood-corpuscles. In the young subject the
of many of these cells have been noticed to be multiple, or to be
with prominences as if budding. The interstices between the
tacular cells are, in sections of the hardened organ, always found
occupied by blood (fig. 555, *bl*), white corpuscles occurring in
larger proportion than in ordinary blood, especially in the neigh-
ood of the Malpighian corpuscles to be immediately described. In
relation to the branched or flattened cells of the pulp, and occupy-
ome of the smaller interstices between them, rounded, unbranched
are seen, larger than white blood corpuscles, but otherwise much
bling them. These cells are amœboid and like the fixed cells of
ulp often contain both red blood corpuscles and clumps of pigment
les.

ood-vessels.—The splenic artery and vein, alike remarkable for
great proportionate size, having entered the spleen by six or more
hes, ramify in its interior, enclosed within the trabecular sheaths
ly described.

e smaller branches of the arteries leave the trabeculæ, and, passing
the proper substance of the spleen, divide into small tufts
terioles arranged in pencils (fig. 556). But before they thus
nate, the adventitious fibrous coat which is prolonged over them
the trabeculæ becomes transformed into lymphoid tissue, which
a comparatively thick sheath along each. This lymphoid sheath
uptly dilated here and there into small oval or spheroidal enlarge-
, measuring on an average $\frac{1}{70}$ of an inch in diameter, but varying

in size from much smaller than this up to $\frac{1}{25}$th of an inch, an resembling the lymphoid follicles met with in the intestine and e These lymphoid expansions may be seen on the surface of a fres of the organ as light-coloured spots scattered in the dark s composing the pulp, and have been long noticed and desc the **Malpighian corpuscles** of the spleen (fig. 554, *cc*; f In some cases the corpuscle is developed upon one side onl arterial wall, upon which it then appears to be sessile; whilst instances—and this is the most frequent in the human s the expansion takes place all round the circumference vessel, by which it then appears to be pierced. In either artery sends off radiating branches to be distributed in the M corpuscle.

Fig. 556.

Fig. 556.—Small artery DOG'S SPLEEN WITH MALPI PUSCLES ATTACHED. 10 (Kölliker).

As just stated, the M corpuscles are localized sions of the lymphoid which the external coa smaller arteries of the formed. The reticulum tissue is comparatively op almost absent towards th of the corpuscle: at the it becomes closer; there ever, no distinct bounda rating it from the retifor of the pulp. The me densely packed with l corpuscles, and the t traversed by blood capilla

The small arteries te in capillaries, which after a longer or shorter course, lose their character, the cells which compose their wall becoming partial rated from one another by elongated clefts; those at the extre the capillary acquiring processes and becoming united by the the connective tissue cells of the pulp. In this manner their bl flow directly into the interstices of the pulp tissue. The veins form a network of intercommunicating spaces within the pulp, co in the same manner as the capillaries terminate; that is to s layer of flattened cells which lines and mainly composes their w being traced back, loses its epithelioid character, and the cells, be thickened and spindle-shaped and their nuclei prominent, are to be separated here and there from each other, and to be co by processes with the cells of the pulp (fig. 555). The small ve a different course from the arteries, for they soon pass to the tr and are conducted upon and within these, freely joining and mosing; whereas the arteries appear to have few or no anas within the substance of the organ.

The small veins within the pulp of the human spleen often

ar transverse markings. These are produced by fine elastic fibres reticulum above described, which encircle the vessels.

n the description above given, it would appear that the blood in passing gh the spleen is brought into immediate relation with the elements of the and no doubt undergoes important changes in the passage; in this respect bling the lymph as it passes through the lymphatic glands. Two modifica- which are probably effected in it may be here pointed out. In the first the lymphoid tissue ensheathing the arteries, together with that composing alpighian corpuscles, would appear, like the same tissue in the lymphatic s, and other parts, to be the seat of the production of pale blood corpuscles. e circumference of this tissue, these may pass into the interstices of the and so into the blood. It is found, in fact, that the blood of the splenic is extremely rich in pale corpuscles. In the second place, red blood- scles may be taken up by the pulp-cells, their colouring matter being ormed into pigment. The splenic cells have, indeed, been noticed, when ned on the warm stage, to take red corpuscles, which were in contact with into their interior.

lymphatics of the spleen form two systems, a *trabecular* and a *perivascular*. essels belonging to the former run in the trabeculæ and are in communica- rith a superficial network in the capsule. The perivascular take origin in terstices of the lymphoid tissue which ensheaths the smaller arteries, and forms the Malpighian corpuscles; they do not, therefore, at first form ct vessels. When these are seen they commonly run in pairs, one on either f an artery, uniting over it by frequent anastomoses, and sometimes lly or wholly enclosing it. At the hilus the two sets of lymphatics join roceed along the gastro-splenic omentum to the neighbouring lymphatic s.

nerves, derived from the solar plexus, surround and accompany the c artery and its branches. They are most probably distributed to the s and plain muscular tissue of the framework.

erature.—*Gray*, Structure and Use of the Spleen, 1854; *Busk and Huxley* on alpighian Bodies, in the Sydenham Society's translation of Kölliker's Histology; *uxley*, in Micro. Jour., II., p. 74; *Billroth*, in Zeitschrift f. wiss. Zoologie, XI., and Arch. XX., 1861; and XXIII., 1862; *W. Müller*, Ueber d. fein. Bau der Milz, and in Stricker's Handbook; *Stieda*, in Virch. Arch., XXIV.; *Schweigger-Seidel*, Arch. XXVII., 1863; *Tomsa*, Wiener Sitzungsb. XLVIII., 1864; *Peremeschko*, ener Sitzungsb. 55, 1870; *Wedl*, Wiener Sitzungsb. 64, 1871; *Kyber*, Arch. f. Anat. VI., 1870, and VIII., 1872; *Rindfleisch* in Berlin, klin. Wochenschr., 1872; *hultze*, in the same journal; *Stoff u. Hasse* in Med. Centralbl., 1872; *Klein* in uart. Journ. of Micro. Sci., 1870.

SUPRARENAL BODIES.

e *suprarenal bodies* or *capsules* (*capsulæ atrabilariæ seu renes succenriati* of old anatomists), are two flattened bodies, belonging to the of organs formerly known as ductless glands, each of which surts the corresponding kidney (fig. 557). The upper border of ght capsule, convex and thin, is often considerably elevated in the e so as to give the body a triangular form. The lower border cave, and rests upon the anterior and inner part of the summit e kidney, to which it is connected by loose areolar tissue: it is and almost always deeply grooved. The posterior surface rests he diaphragm. The anterior surface presents an irregular fissure the *hilus*, from which the suprarenal vein emerges (fig. 558, *v*). ght capsule is pyramidal in shape and projects more above the

kidney than the left. It is covered by the liver (at the impressio suprarenalis). The left capsule is more crescentic in form and is generally larger than the right. In most cases it only just projects above the kidney. The concave border rests against the convex inner border of the head of the kidney. It is in contact below with the pancreas, above and externally with the spleen. Its posterior surface rests against the left crus of the diaphragm; its anterior surface is covered by the stomach and pancreas.

Fig. 557.

Fig. 557.—FRONT VIEW OF THE RIGHT KIDNEY AND SUPRARENAL BODY OF A FULL-GROWN FŒTUS (Allen Thomson).

This figure shows the lobulated form of the fœtal kidney, *r*; *v*, the renal vein and artery; *u*, the ureter; *s*, the suprarenal capsule, the letter is placed near the sulcus in which the large veins (*v'*) are seen emerging from the interior of the organ.

Fig. 558.

Fig. 558.—SECTION OF THE SUPRARENAL BODY (Allen Thomson).

A vertical section of the suprarenal body of a fœtus, twice the natural size, showing the lower notch by which it rests on the summit of the kidney, and the anterior notch by which the veins issue, together with the distinction between the medullary and cortical substance.

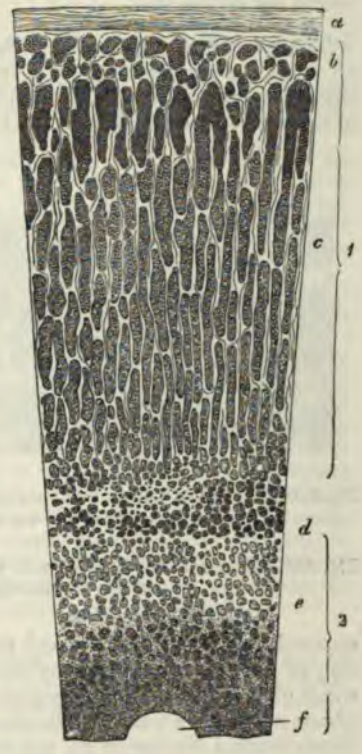
The suprarenal capsules measure from an inch and a quarter to an inch and three-quarters from above down, and about an inch and a quarter from side to side; their thickness is from one-sixth to one-quarter of an inch. The *weight* of each in the adult is from one to two drachms.

Structure.—Besides a covering of areolar tissue mixed frequently with much fat, the suprarenal capsules have a thin fibrous investment. On the exterior their colour is yellowish or brownish-yellow. When divided (fig. 558), they are seen to consist of two substances: one, *external* or *cortical*, is of a deep yellow colour, firm and striated, and forms the principal mass of the organ; the other, *internal* or *medullary*, is in the adult of a dark brownish-black hue, and so soft and pulpy that some anatomists have erroneously described a cavity within it.

The **fibrous investment** (fig. 559, *a*), which is distinguishable into

looser and an inner firmer part, is so intimately connected with er parts that it cannot be removed without lacerating the sub- ructure. Its deeper layers contain plain muscular cells, at least animals: it is continuous with the septa which enter into the n of the substance of the organ.

Fig. 559.



—VERTICAL SECTION OF SUPRA- ODY: HUMAN. MAGNIFIED (Eberth).

al substance; 2, medullary sub- , capsule; *b*, zona glomerulosa; sciculata; *d*, zona reticularis; *e*, medullary cells; *f*, section of a

ortical part of the supra dy, examined in a section ow magnifying power (fig. is seen to consist of a stroma, in which are im- column-like, intercommuni- oups of cells (*c*). The groups on an average $\frac{1}{100}$th of an diameter, and are arranged to the surface of the In the deepest part of the owever, the colour is darker, columnar arrangement is stroma being more equally ed (*d*); and immediately the fibrous coat there is narrow zone in which the ncloses what in section look nded or oval spaces occu- groups of cells, which are he outer ends of the groups above men-).

ner and outer layers have been named by J. Arnold respectively zona and zona glomerulosa, while he applies the term zona fasciculata to part (*c*); but the transition from one of these parts to another is not r indicated by any line of demarcation.

lls which form the groups and columns of the cortical substance nedral in form (fig. 560): their protoplasm is finely reticular, unfrequently contains yellowish oil globules. The cells vary oth to $\frac{1}{1350}$th of an inch in size: each has a clear round

animals (horse, dog), the spaces of the zona glomerulosa are occupied ly arranged long columnar cells, set around a sort of lumen, and looking part of a glandular tube. In man, however, most of the cells of this olyhedral, like those of the other zones.

all arteries, entering from the surface, run in the septa parallel to the frequently *anastomosing together* between them, and surrounding each

group of cells with a fine capillary network. Small bundles of nerves wards in the septa between the columns to reach the medullary part of t and their fibres begin to spread out in the zona reticularis, but do not be distributed to the cortical substance.

Lymphatics run in the trabeculæ of the cortical substance and are with cleft-like spaces between the trabeculæ and the cell-columns, with fine clefts between the cells within the columns (Klein). They com with efferent valved lymphatics both in the fibrous coat and in the around the central vein.

The **medullary part** (fig. 559, 2) of the suprarenal capsule is off from the cortical part by a layer of loose connective tissue. thinner parts of the adult organ there is no medullary part, and of connective tissue referred to is found separating the deep surfac

Fig. 560. Fig. 561.

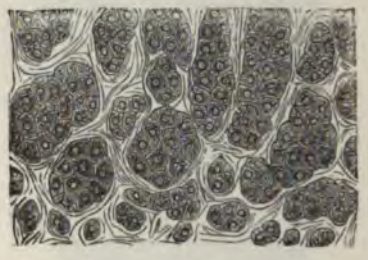


Fig. 560.—Cells and cell-groups from the outermost layer of the cortical of the suprarenal body. Highly magnified (Eberth).

Fig. 561.—A small portion of the medullary part of the suprarenal of the ox (Eberth). Highly magnified.

opposed portions of the cortical part; but in the young state the tion of cortical and medullary portions probably extends throug whole gland. The medullary part is pervaded by large venous ca which receive the whole of the blood which has passed through th These venous capillaries are supported by the fibrous stroma, wh contains, especially in man, a number of bundles of plain muscu disposed parallel to the course of the larger veins, and forming plete investment to the issuing suprarenal vein (v. Brunn). The arrangement of the stroma is reticular; in its meshes are enclose of cells (fig. 561), which differ from those of the cortex in bei irregular in form, of a clearer aspect and destitute of oil-globules over they become stained of a deep brown colour, by solutio chromate of potash, whereas the cortical cells are but slightly ti that re-agent.

In some animals the medullary cells contain a large amount of reddi pigment, but this is not generally the case in the human subject, the d of the medulla being chiefly due to the blood within its numerous vess

The bundles of nerves which pass through the cortical subst between it and the medullary substance, and then form a copi lacement which extends through the whole medullary stroma.

observers (Leydig and Luschka) have regarded the cells of the me- substance as nerve-cells. Moers and others describe ganglion-cells nervous plexuses in the medulla, and there are also ganglia on the which ramify in the fibrous investment (Henle). The medullary nce receives its blood by the continuation inwards of the capillary rk of the cortex. The blood is collected by venous radicles which into the stems in the centre of the organ and these emerge at the

els.—The suprarenal bodies receive *arteries* from three sources, viz., from ria, the phrenic, and the renal arteries.

ins, which pass out from the centre, are usually united into one for each . The right vein enters the vena cava inferior immediately, whilst the left, a longer course, terminates in the left renal vein.

ves.—The nerves which are exceedingly numerous are derived from the plexus of the sympathetic, and from the renal plexuses. According to nann, some filaments come from the phrenic and pneumogastric nerves. are made up mainly of medullated fibres, of different sizes, and they have small ganglia upon them before entering the organ. The nerves are ally numerous in the lower half, and inner border.

ssory suprarenal capsules are occasionally met with, attached by con- tissue to the main bodies; and varying from a small size up to that of a According to Duckworth they possess no medullary part.

ction.—Nothing is known positively with regard to the function of the nal capsules. The opinion which has met with most acceptance among ologists is that these bodies belong to the class of blood-vascular glands, and some influence upon the elaboration or disintegration of nutritive material. roduct of the cell-activity, whatever it may be, is believed by Klein to be d off by the lymphatics of the organ, as in the analogous case of the thyroid

Bergmann, however, who was the first to point out the richness of their ve supply, suggested that they were parts of the sympathetic nervous m, and in this opinion he has been followed by Leydig and Luschka. A ed tint of skin, together with progressive emaciation and loss of strength, quently found in conjunction with various forms of disease more or less in- ng and altering the structure of these bodies (Addison's disease).

erature.—*Bergmann*, Inaug. Diss., Göttingen, 1839; *Ecker*, Der feinere Bau der nieren, &c., 1846; *Frey*, Article in Todd's Cyclopædia, 1849; *G. Harley* in the l, 1858; *Moers* in Virch. Arch., 1864; *Duckworth* in St. Barthol. Hosp. Reports, ; *Holm* in Wiener Sitzungsb., 1866; *Grandry* in Journ. de l'anat., 1867; *Eberth* icker's Handbook, 1871; v. *Brunn* in Arch. f. mikr. Anat., VIII.; and Göttinger ., 1873; *Creighton* in Proc. R. S., 1877 and Journal of Anat. and Phys., XIII.; *Auri* in Quarterly Journ. of Micro. Sci., 1882.

THE URINARY ORGANS.

e urinary organs consist of the *kidneys*, the glands by which the is secreted, and the *ureters*, *bladder*, and *urethra*, serving for its tion and evacuation.

THE KIDNEYS.

e *kidneys*, two in number, are deeply seated in the loins, lying n each side of the vertebral column, at the back part of the ninal cavity, and behind the peritoneum. They are on a level the last dorsal and the two or three upper lumbar vertebræ, the kidney being usually a little lower than the left, probably in luence of the *vicinity of the large* right lobe of the liver. They

are maintained in this position by their vessels, and by a quan surrounding loose areolar tissue, which usually contains much fat adiposa).

Fig. 562.

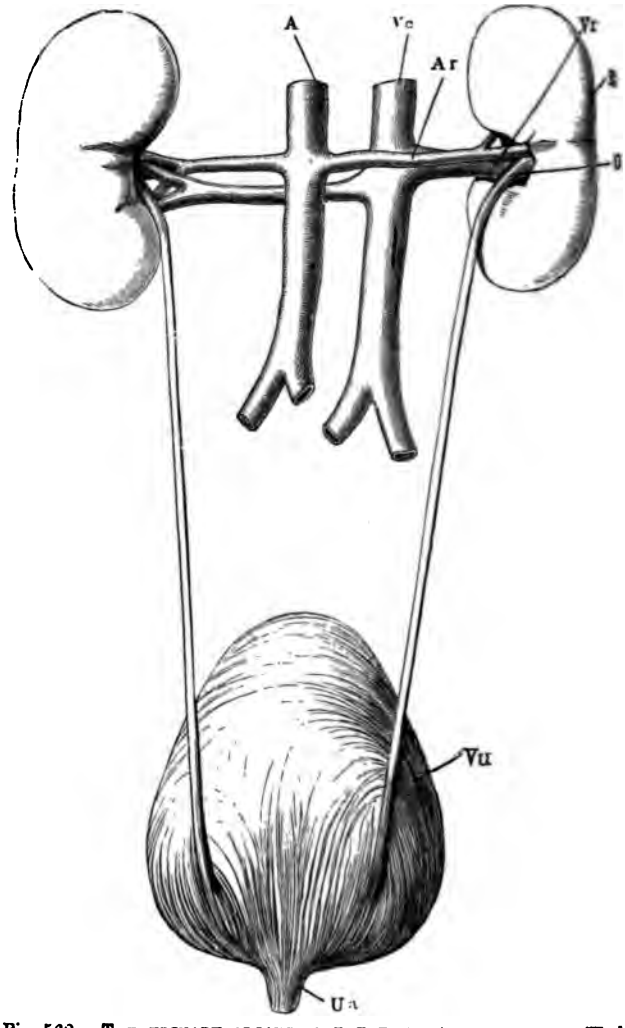


Fig. 562.—THE URINARY ORGANS OF THE FEMALE FROM BEHIND (Hen

R, right kidney; *U*, commencement of the ureter; *A*, aorta; *Ar*, right re *Vc*, vena cava; *Vr*, right renal vein; *Vu*, urinary bladder; *Ua*, comme urethra. ½

The kidneys measure about 4 inches in length, 2½ inches in and 1¼ inch or more in thickness. The left is usually lo narrower than the right. The weight of the kidney is usually be about 4½ oz. in the male, and somewhat less in the female.

rm and Connections.—The surface of the kidney is smooth, and leep red colour. Its form is peculiar: it is compressed from before ards with a convex outer, and concave inner border, and somewhat ed extremities, the upper extremity being set somewhat further han the lower.

e *anterior surface*, more convex than the posterior, looks somewhat rds, and is partially covered at its upper end by the peritoneum. nodenum and commencement of the transverse colon, both destitute itoneum behind, are in contact with the anterior surface of the right y, and the descending colon with that of the left. The front of ght kidney, moreover, touches the under surface of the liver, and f the left the fundus of the stomach, the latter producing a slight ve impression on the kidney. Below, the anterior surface of the dney comes in contact with the pancreas. The *posterior surface*, ded in areolar tissue, rests firstly upon the lower part of the arch e diaphragm, in front of and below the twelfth rib; secondly, on nterior layer of lumbar fascia, covering the quadratus lumborum e; and, lastly, on the psoas muscle which corresponds with a w concave impression on the posterior surface of the organ. The *al border*, convex in its general outline, is directed somewhat back- towards the wall of the abdomen. On the left side it is in contact ie upper two-thirds of its extent with the spleen. The *internal* , concave and deeply excavated towards the middle, is directed a downwards and forwards. It exhibits a longitudinal *fissure* led by an anterior and posterior lip, and named the *hilus of the y*, at which the vessels, the excretory duct, and the nerves enter or ut. In this hilus, the renal vein lies in front, the artery and its hes next, and the expanded excretory duct or ureter behind and ds the lower part. The *upper end* of the kidney, which is larger the lower, is thick and rounded, and supports the suprarenal cap- which descends a little way upon its anterior surface. This end of idney reaches, on the left side, to about the upper border of the h dorsal vertebra, and on the right, half an inch lower. It is more- directed slightly inwards, so that the upper ends of the two kidneys earer to each other than the lower ends, which are smaller and some- flattened, diverge slightly from the spine, and reach nearly as low crest of the ilium.

ieties.—The kidneys are sometimes longer and narrower, and sometimes r and more rounded than usual. Occasionally one kidney is very small the other is proportionately enlarged. They may be situated lower down sual, even in the pelvis.

ances are now and then met with in which the two kidneys are joined by ower ends across the front of the great blood-vessels and vertebral column. njunct organ has usually the form of a horse-shoe. Sometimes two united s are situated on one or other side of the vertebral column, in the lumbar , or, but much more rarely, in the cavity of the pelvis. In other very rare three glandular masses have been found, the supernumerary organ being either in front or on one side of the vertebral column, or in the pelvic cavity.

ucture.—The kidney is surrounded by a proper fibrous coat, forms a thin, smooth, but firm investment, closely covering the . It consists of dense areolar tissue, with numerous fine elastic and can easily be detached from the substance of the gland, ich it adheres by *minute* processes of connective tissue and

vessels. Underneath the capsule in the human kidney is an inc layer of plain muscular fibres.

On splitting open the kidney by a longitudinal section, from i to its inner border, the fissure named the hilus (fig. 563, *h*, *h*) to extend some distance into the interior of the organ, forming called the *sinus* of the kidney (*s*). This is enclosed on all side at the hilus by the solid substance of the organ; and is line inward prolongation of the fibrous coat. The solid part co *cortical* and *medullary* substance; the latter being arranged in conical masses named "pyramids of Malpighi," with their bro (*b*, *b*) directed towards the surface, and their points towards th where they form prominent *papillæ*. The pyramids are imb the cortical substance, which separates them from each ot encloses them everywhere except at the papillæ, which emerg and project into the sinus.

The external or cortical substance (*a*) is situated immediatel the fibrous capsule, and forms the superficial part of the organ

Fig. 563.

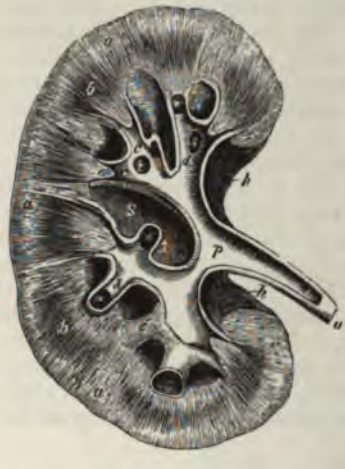


Fig. 563.—PLAN OF A LONGITUDIN THROUGH THE PELVIS AND SUB THE RIGHT KIDNEY. ONE-H NATURAL SIZE.

a, the cortical substance; *b*, part of two of the pyramids of *c*, *c*, the divisions of the pel calices, or infundibula, laid open of these unopened; *d*, *d*, summ pyramids or papillæ projecting int *e*, *e*, section of the narrow pa pyramids near the calices; *p*, enlarged portion of the ureter w kidney; *u*, the ureter; *s*, the the hilus.

out its whole extent to the about two lines, and moreov prolongations inwards (*sept num*, or *columnæ Bertini*) the pyramids as far as the si bases of the papillæ. It is of uniform light crimson brown appearance, and is soft and easily la in directions vertical to the surface. The medullary portion kidney is more dense than the cortical, and is distinctly striated to its consisting of small diverging uriniferous tubes, and to its vessels being arranged in a similar manner. There are general than twelve pyramids, but their number is inconstant, varying fro to eighteen. Towards the papillæ the pyramids are of a lighte than the cortical substance, but at their base they are usually and darker.

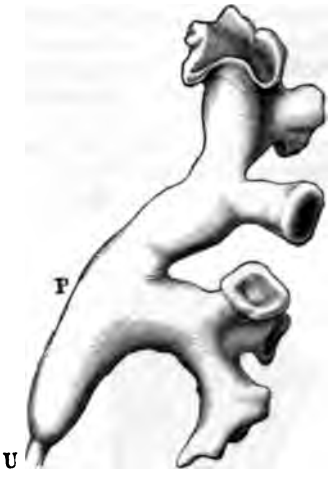
Excretory apparatus.—On squeezing a fresh kidney wh been split open, a little urine will be seen to drain from the pa fine orifices on their surface. The secretion is carried away veyed into the bladder by the ureter. This long tube on being up to the kidney is seen to be somewhat enlarged, and then to as it enters the fissure, into a large funnel-shaped dilatation na

ig. 546, P). This within the sinus, divides usually into three, etimes only two primary tubular divisions, and these at length a larger number of short, truncated but comparatively wide s named *calices* or *infundibula*, which receive the papillæ into de mouths and are attached around the bases of those prominences nich, of course, they catch the issuing urine.

—CAST OF THE INTERIOR OF THE UPPER THE URETER (Henle).

P, pelvis; *U*, ureter.

Fig. 564.



ngle calix often surrounds two, nes even three papillæ, which hat case united together; hence, ces are in general not so nume- the papillæ. The spaces between ces are occupied by a consider- ount of fat, imbedded in which the main branches of the renal

the rest of the ureter, the pelvis ater part of the calices consist coats, viz., a strong external and elastic tunic, which becomes ous around the bases of the with that part of the proper the kidney which is continued sinus; secondly, a thin internal mucous coat, which, or at least elium, is reflected over the summit of each papilla; and thirdly, these two, a double layer of muscular fibres, longitudinal and . The longitudinal fibres are lost near the extremity of the calix, circular fibres, according to Henle, form a continuous circular round the papilla where the wall of the calix is attached to it.

yramidal masses found in the adult kidney indicate the original sepa- f this gland into lobules in the earlier stages of its growth. these primitive lobules is in fact a pyramid surrounded by a proper in- of cortical substance, and is analogous to one of the lobules of the kidneys seen in many of the lower animals. As the human kidney con- be developed, the adjacent surfaces of the lobules coalesce and the comes a single mass; the contiguous parts of the originally separate investments, being blended together, form the partitions between the already described. Moreover, upon the surface of the kidney even in , after the removal of the fibrous capsule, faintly marked furrows may on the cortical substance, opposite the intervals in the interior between al Malpighian pyramids; and not unfrequently instances occur in which separation of the original lobules by grooves remains apparent in the ney.

uli uriniferi.—On examining the summit of one of the papillæ , especially with the aid of a lens, a number of small orifices seen varying in diameter from $\frac{1}{300}$th to $\frac{1}{200}$th of an inch. They quently collected in large numbers at the bottom of a slight on or *foveola* found near the summit of the papilla, but most ly the surface *is pitted over with* about a score of small de-

pressions of this sort. On tracing these minute openings into
stance of the pyramids, they are discovered to be the mouths of sm
or ducts, the *uriniferous tubes* before mentioned, which thus op
the surface of the several papillæ into the interior of the calices.

As these tubuli pass up into the pyramidal substance, the
cate again and again at very acute angles, their successive
running close together in straight and slightly diverging lines,
continue thus to divide and subdivide until they reach the s
bases of the pyramids, whence they pass, greatly augmented in
into the cortical substance. In the cortical part the straigh
belonging to a Malpighian pyramid are continued for some way, i
groups or bundles, the tubules in the centre of which approac
the surface than those at the sides. These bundles are know
medullary rays (fig. 565, *m*) of the cortex, and the cortical s
between and around them is termed, on account of the intricate
ment of its tubules, the *labyrinth of the cortex*.

Fig. 565.

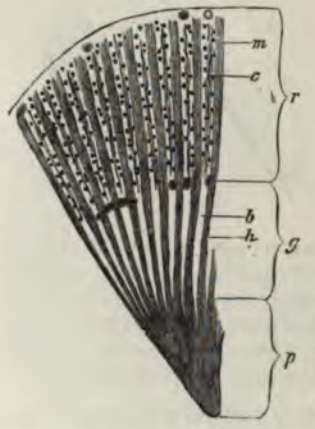


Fig. 565.—Section through part of kidney (Ludwig).

p, papillary and *g*, boundary zones of th
r, cortical layer; *h*, bundles of tubul
boundary layer, separated by spaces, *b*,
bunches of vessels (not here represented)
longed into the cortex as the medullary r
intervals of cortex, composed chiefly of
tubules, with irregular rows of glomerul
the medullary rays.

The part of the pyramid w
nearest the cortical substance co
number of pencil-like bundles
blood-vessels, which originating fr
rial and venous arches at the jun
cortex and medulla, dip into the
and thus commence the separatio
tubules into the bundles which
tinued into the cortex as the m
rays. The portion of the pyramid which is thus broken up is
the *boundary zone* (fig. 565, *g*).

Course of the tubules.—The tubes commence in the labyrint
cortical substance by spherical dilatations enclosing like a caps
vascular Malpighian tufts to be afterwards described.

Emerging from this dilatation (fig. 566, 1), which is known
capsule, by a narrow neck (2), the tubule is at first convoluted a
(*first convoluted tubule*), but on approaching the medullary
becomes nearly straight with a slight tendency to a spiral (*spira*
of Schachowa, 4). At the junction of cortex and medulla th
tube rapidly narrows and passes straight down through the l
zone towards the apex of the pyramid. After a shorter or longer
however, it loops upwards again (6) becoming enlarged in the b
zone (7), but somewhat smaller again above this (8, 9) where it
again up the medullary ray. The part of the uriniferous tube wh
dips down towards the papilla and turns upwards again is known
looped tubule of Henle. On emerging from the medullary ray the t

ized by great irregularity of outline (*irregular tubule*, 10) gain becoming convoluted (*second convoluted tubule*, 11). his last is connected with one of the collecting tubules of the y ray by a small *junctional tubule* (12), and the *collecting tubes* (13,

Fig. 566.

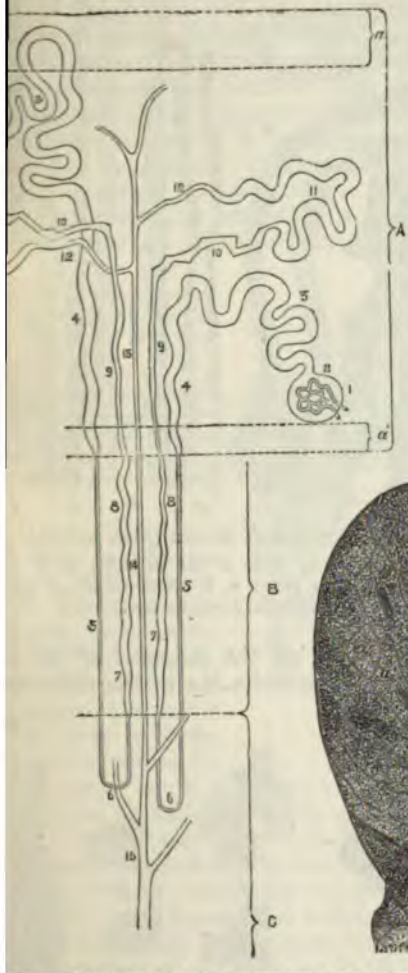
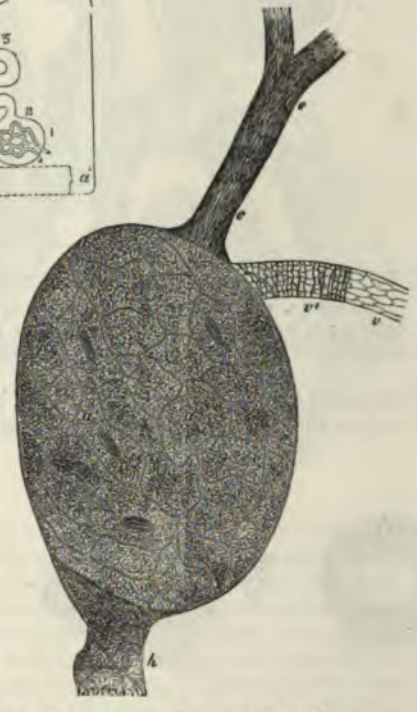


Fig. 567.



566.—Diagram of the course of two uriniferous tubules (Klein).

x ; B, boundary, zone C, papillary zone of the medulla ; *a*, *a'*, superficial and s of cortex, free from glomeruli. For the explanation of the numerals, see

—Malpighian corpuscle from the rabbit's kidney : nitrate of silver preparation. Highly magnified (Ludwig).

fferens, showing its epithelial lining : at *v'*, the transverse muscular fibres are *e*, vas efferens ; *a*, *a'*, basement membrane of capsule with epithelioid mark- ng at *h* into that of the *commencing uniferous* tubule.

14, 15) uniting with one another, as already noticed, become gradually larger as they pass to open as *excretory tubes* at the summit of the papilla.

Structure of the tubules.—The tubules consist in every case of a

Fig. 568.

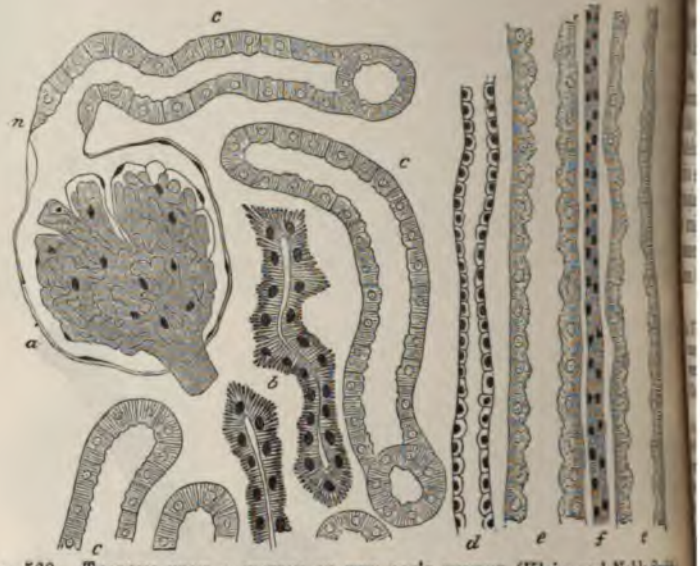


Fig 568.—TUBULES FROM A SECTION OF THE DOG'S KIDNEY (Klein and Noble Smith).

a, Capsule, enclosing the glomerulus; *n*, neck of the capsule; *c*, *c*, convoluted tubules; *b*, irregular tubules; *d*, collecting tube; *e*, *e*, spiral tubes; *f*, part of the ascending limb of Henle's loop, here (in the medullary ray) narrow.

basement membrane and epithelium, but the character of the latter as well as the size of the tubes varies considerably in the different parts.

Fig. 569.

Fig. 569.—TO ILLUSTRATE THE STRUCTURE OF THE EPITHELIUM OF THE CONVOLUTED TUBULES (from Heidenhain).

d, section of a convoluted tubule from the rat, showing the unaltered protoplasm occupying a circular area around the nucleus of each cell; *a*, *b*, *c*, isolated cells from the convoluted tubules of the rat; *e*, isolated cells from the dog's kidney, viewed from the inner surface, and showing the irregular contour of the protoplasm; *e*, *f*, isolated cells from the newt, showing the rods and the homogeneous cuticular layer.

Fig. 570.—PART OF A CONVOLUTED TUBULE OF THE DOG'S KIDNEY (Heidenhain).

apsule (fig. 568, *a*), is lined by a layer of flattened cells, which is ed over the contained tuft of blood-vessels, dipping between the te bunches of which this is composed. This layer is much more recognized in the fœtus and young subject than in the adult 71). At the *neck* the epithelium becomes cubical. It has been by Hassall in the sheep, horse, and rabbit, and more recently lein in the mouse, that the epithelium here is provided with and it is not improbable that the same may be the case in all nals. In lower vertebrates as in the frog, the existence of cilia place has long been known. The *first convoluted tubule* has an lium of a peculiar character (Heidenhain). The part of the cell encloses the nucleus is composed of ordinary granular-looking asm, but the part next the basement membrane is chiefly made up ight or nearly straight rods or fibrils placed vertically to the nt membrane and extending a variable distance towards the (figs. 569, 570), but usually occupying the greater part of the cell,

Fig. 571.

.—Section of cortical nce of kidney: human . Highly magnified).

nerulus with blood-vessels developed; *c*, epithelium it continuous with *d*, epithelium lining Bow- apsule; *f*, *f*, convoluted

gh there is always a n of homogeneous nce bounding the owards the lumen 9, *f*). The nucleus is al. The cells are with ty separated from one r, at least in some s (*e.g.*, dog) owing to ls possessing lateral ridge-like processes (fig. 569, *e*) which interlock ne another (Schachowa). The *spiral tubule* of Schachowa is the nation of the convoluted tubule into the medullary ray, and es a similar epithelium (fig. 568, *e*). Towards its termination, how- ne cells become shorter and less distinctly fibrillated, but split up mpletely into lateral ridges with intervening furrows, especially in rt of the cell next the basement membrane, so that the cells bear nat the aspect of columns deeply fluted at their base. Between nted cells, others of clearer aspect are found fitting in, and having nded base which extends partly underneath them. According to owa they are present also in the convoluted tubules proper.

ne narrow tube which forms the *descending limb of Henle's loop*, the loop itself, the epithelium is quite low, and flattened against ement membrane. The protoplasm is clear and the nucleus ent. The ridge-like processes at the base of the cells are said not together absent even here.

ne *ascending limb of the looped* tubule the epithelium again takes

on the character which is exhibited in the first convoluted tubes, but the cells are rather smaller, the lumen of the tube larger, and the intracellular rods not so long as in those t cells of this segment are sometimes set obliquely so as to o another. In the human subject they contain brown pigmen (Klein).

In the *irregular tubules* on the other hand the rod-like st the cells is very distinct (fig. 568, *b*). The cells are ver in size, the irregularity of the tubules being thus compens the lumen rendered nearly the same throughout. The n oval.

The *second convoluted tubule* (intercalary tube of Schweigg is like the first in size, but has a different kind of epithelium. which are rather long, with a relatively large nucleus, present a highly refractive appearance, and where they rest on the m propria, the protoplasm exhibits projections which fit between neighbouring cells.

The *junctional tubule*, which unites the last-named to the tubes, is narrow, but its lumen is relatively large. It is lined flattened or cubical cells ; but between them some cells are fou are similar in appearance to the cells which line the segm described.

The *collecting tubes*, which are characterised by their straight c very distinct lumen (fig. 568, *d*) are lined by a clear cubical ep the cells of which are at first somewhat irregular, but become lo more regular as the tubes approach the papilla, so that in t collecting or *excretory tubes* the form of the cells is typically modified only by the form of the surface which they cover. largest tubes the basement membrane is said to be absent, thelium cells resting directly upon the connective tissue.

Klein describes a very delicate nucleated membrane lining the tub the epithelium, in all the tubes except the descending limb of Henle in the loop itself.

Blood-vessels.—The kidneys are highly vascular, and rec blood from the renal arteries, which are very large in proport size of the organs they supply. Each renal artery divides in five branches, which, passing in at the hilus, between the vein a may be traced into the sinus of the kidney, where they lie am infundibula, together with which they are usually embedded in of fat. Penetrating the substance of the organ between th the arterial branches enter the cortical substance which between the pyramids of Malpighi, and proceed in this, acc by a sheathing of areolar tissue, and dividing and subdividing the bases of the pyramids, where they form arches between th and medullary parts, which however are not complete, and in th differ from the freely anastomosing venous arches which accomp From the arches smaller "interlobular" arteries (fig. 572, *ai*) off, which pass outwards between the medullary rays and am convoluted tubules, pursuing a nearly straight course towards th of the organ. As they proceed they give off at intervals short an curved branches which proceed without further division to th ends of the uriniferous tubules. Within the capsule the sm

breaks up into a larger number of capillary vessels convoluted arrangement, and are closely held together sue to form a spheroidal vascular tuft, the *glomerulus*

Fig. 572.

Fig. 572.—DIAGRAM OF THE DISTRIBUTION OF THE BLOOD-VESSELS IN THE KIDNEY (from Ludwig).

ai, ai, interlobular arteries; *vi, vi*, interlobular veins; *g*, a glomerulus; *vs*, stellate vein; *ar, vr*, arteriæ et venæ rectæ forming pencil-like bundles, *ab, vb*; *vp*, venous plexus in the papillæ.

Fig. 573.

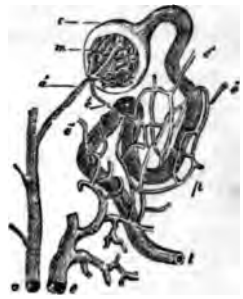


Fig. 573.—DIAGRAM SHOWING THE RELATION OF THE URINIFEROUS TUBULES TO THE BLOOD-VESSELS (after Bowman).

a, one of the interlobular arteries; *a'*, afferent artery passing into the glomerulus; *c*, capsule of the glomerulus; *t*, convoluted tube; *e'*, *e'*, efferent vessels which subdivide in the plexus *p*, surrounding the tube, and finally terminate in the interlobular vein, *c*.

of Malpighi. A vein (efferent vessel) smaller than the artery, emerges from the glomerulus close to the point where the artery enters; but, instead of joining with other small veins to form larger venous trunks, as is the case in other organs, the efferent vessel divides into branches after the manner of an artery, and from these arises a dense network of capillaries which everywhere ramify over the walls of the uriniferous tubules (fig. 573), the meshes of the network being poly-

the convoluted tubules and elongated amongst the nedullary rays. But the efferent vessels from the lower- break up wholly into pencils of straight vessels (false h pass directly into the boundary layer of the medulla, the continuation downwards of the medullary rays into

The renal arteries give branches likewise to the capsule of the kid anastomose with branches of the lumbar arteries, and that so freely th was able partially to inject the kidneys of a dog from the aorta after arteries had been tied.

The blood is conveyed from the cortex of the kidney by *in veins* which accompany the interlobular arteries, and join the c of the venous arches which lie between the medulla and cortex, by veins which lie close beneath the capsule of the organ,

Fig. 574. Fig. 575.

Fig. 574.—INJECTED GLOMERULUS FROM THE INNER PART OF THE CORTICAL OF THE HORSE'S KIDNEY. 70 DIAMETERS (from Kölliker after Bowm

a, interlobular artery; *af*, afferent vessel; *m*, *m*, convoluted vessels of the *ef*, efferent vessel; *b*, its subdivision in the medullary substance.

Fig. 575.—LONGITUDINAL SECTION OF A PART OF THE MEDULLARY SUBSTANC ADJACENT CORTICAL SUBSTANCE OF THE KIDNEY, SHOWING THE BLOOD-VESSEL (from Southey).

The figure is designed principally to show the origin of the false vasa r interlobular arteries; Aa, transverse section of anastomotic arch; CV, cort *m*, glomeruli; R, R, false vasa recta; MV, medullary veins.

origin by the conveyance of minute venous radicles, so as to stellate appearance (*venæ stellulæ*). These vessels, which rece from the capsule of the kidney, pass inwards through the cortex join the venous arches.

With the exception of the blood brought by the false arter

lood supply of the medulla is to a great extent independent of that
e cortex, although of course the capillary network is continuous
ghout. The pyramids are chiefly provided with blood by vessels
i come off directly from the concave side of the arterial arches, and
g down into the boundary layer of the medulla there divide to
bunches or pencils of parallel or slightly diverging minute vessels
arteriæ rectæ, fig. 572, *ar*), which by alternating with the bundles
miferous tubules which are passing up to the cortex to form the
llary rays, produce the characteristic streaked appearance of this
f the pyramid.

e long meshed capillary network which is supplied by the true
e rectæ, is continued down to the apex of the papilla. Here the
of the pyramid commence in a close plexus of small venous
es surrounding the excretory ducts near their orifices (fig. 572, *vp*).
g outwards towards the base of the pyramid, and receiving lateral
bes at acute angles from its capillary network, the small veins
e collected together into pencils, the vessels of which (venæ
) are intermixed with the arteriæ rectæ, and unite into vessels
open into the concave side of the venous arch.

e venous trunks thence proceed, in company with the arteries,
gh the cortical septula between the pyramids, to the sinus of the
y. Joining together, they escape from the hilus, and ultimately
a single vein, which lies in front of the artery, and ends in the
r vena cava.

mphatics.—The lymphatics of the kidney are numerous, consisting of a
ficial set forming a plexus in the fibrous capsule, and of deep lymphatics
issue from the hilus with the blood-vessels. Ludwig and Zawarykin have
that there exists a network of freely intercommunicating lymphatic
between the tubules, in communication both with the lymphatics of the
e and those which issue with the blood-vessels at the hilus. They are most
ant in the cortical substance.

ves.—The nerves which have been traced into the kidneys are small. They
immediately from the renal plexus and the lesser splanchnic nerve, and
n filaments derived from both the sympathetic and cerebro-spinal systems.
may be traced accompanying the arteries as far as their finer branches, but
ncertain how they end.

ertubular Stroma.—Between the tubules and vessels of the kidney,
gh they are disposed closely together, a small amount of interstitial
nce of the nature of connective tissue is found. It has a more fibrous
ter in the vicinity of the chief ramifications of the blood-vessels, and also
l the Malpighian corpuscles, and the tubes of the medullary substance.
roma is more abundant in the cortical substance, where it contains many
tive tissue corpuscles, than in the greater part of the medullary substance;
is very abundant towards the apices of the papillæ.

erature.—*C. Ludwig*, Article "Kidney" in Stricker's Handbook, 1871 (where
erature up to that time will be found); *Eberth*, in Med. Centralbl., 1872; *Heiden-*
n Arch. f. mikr. Anat., X. 1873; *W. Pye*, in Journ. of Anat. and Physiol., X.
Panseh, in Arch. f. Anat., 1876 (position of kidney); *S. Schachowa*, Untersuch.
fieren, Diss., Berne, 1876; *Drasch*, in Wiener Sitzungsb., 1877; *Langhans*, in
Arch., 1878; *Budge*, in Deutsche med. Wochenschr., 1878; *Buchhammer*, in
f. Anat., 1879 (varieties); *Cornil*, in Comptes rend., 1879; *Runeberg*, in Nord.
rk., XI; *Henschen*, Akad. Afhandl. in Upsala, 1879.

ureter.

The ureters measure from fourteen to sixteen inches
ordinary width is about that of a goose-quill. They
however, dilated at intervals, especially near the l
narrowest part of the tube, excepting its orifice, is that
walls of the bladder.

Each ureter passes at first obliquely downwards
enter the cavity of the true pelvis, and then curv
inwards, to reach the base of the bladder. In its wh
close behind the peritoneum, and is connected to neighb
loose areolar tissue. Superiorly, it rests upon the pso
crossed very obliquely from within outwards, by the s
which descend in front of it. The right ureter is clo
vena cava. Lower down, the ureter passes either ove
the external iliac vessels, behind the termination of t
right side and the sigmoid flexure of the colon on the le
into the pelvis, it enters the fold of peritoneum forming
ing posterior false ligament of the bladder, and, reachin
bladder near the base (*u*, fig. 577), runs downwards
contact with it, below the obliterated hypogastric arter
upon its inner side, in the male, by the vas deferens (
down between the ureter and the bladder. In the fe
run along the sides of the cervix uteri and upper pa
before reaching the bladder.

Having arrived at the base of the bladder, about t
from one another, the ureters enter its coats, and ru
through them for about three-quarters of an inch, ope
the inner surface by two narrow and oblique slit-like
are situated, in the male, about an inch and a half behi
orifice, and about the same distance from each other
passage of the ureter through the vesical walls, while al
to flow into the bladder, has the effect of preventing its

Structure.—The walls of the ureter are pinkish or
colour. They consist of an external fibrous coat, a mid
muscular tissue, and a mucous lining. The muscular c

its base turned backwards and somewhat downwards, whilst its ape
directed forwards over the symphysis pubis. When moderately full
is still contained within the pelvic cavity, and has a rounded form
577, *a*), but when completely distended, it rises above the brim of the
pelvis, and becomes egg-shaped; its larger end, which is called the
base, or *fundus*, being directed backwards towards the rectum in the
male and the vagina in the female; and its smaller end, or

Fig. 577.

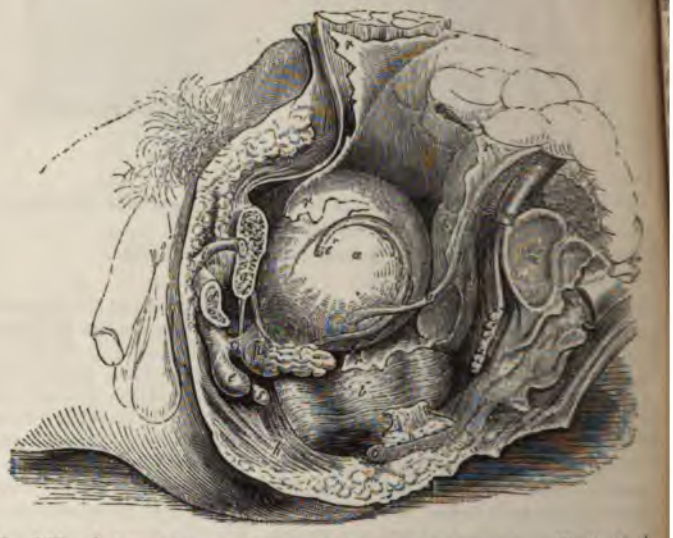


Fig. 577.—Lateral view of the viscera of the male pelvis (R. Quain).

The left hip-bone has been disarticulated from the sacrum, the spinous process of the ischium cut through, and the pubis divided to the left of the symphysis; *a*, bladder; *b*, *b'*, rectum; *c*, membranous part of the urethra; *d*, section of the left corpus cavernosum; *e*, bulb of the spongy body of the urethra; *f*, Cowper's gland; *g*, section of the body of the pubis; *h*, sphincter ani muscle; *i*, part of the left vas deferens; *k*, articular surface of the sacrum; *n*, divided spine of the ischium; *o*, coccyx; *p*, prostate gland; *r*, *r*, peritoneum; *r'*, recto-vesical pouch; *u*, left ureter; *v*, left vesicula seminalis.

resting against the lower part of the anterior wall of the abdomen. Immediately in front of the base is the thickened portion often named the *cervix*, or *neck*, from which the urethra abruptly leads off.

The long axis of the distended bladder is directed nearly horizontally from the base to the summit, in a line from the coccyx to a point somewhat above the symphysis pubis. In being gradually distended the bladder curves slightly forwards, so that it becomes more convex behind than in front, and its upper end is by degrees turned more and more towards the front of the abdomen. Lastly, the bladder, when filled, appears slightly compressed from above downwards, so that its diameter in that direction is less than from side to side. In its ordinary state, the longest diameter in the male is from base to summit: but in the female its breadth is often greater than its height. During infancy the bladder is pyriform when distended, and lies chiefly in the abdomen

nnections.—While freely moveable in all other directions upon unding parts, the bladder is fixed below to the walls of the pelvis he neck, and by fibrous bands given off from the recto-vesical a (see Vol. I. p. 337), named the *true ligaments* of the bladder. It is orted, moreover, by strong areolar connections with the rectum or na, according to the sex, in a slighter degree by the two ureters, the erated hypogastric arteries and the urachus, by numerous blood-ls, and, lastly, by a partial covering of the peritoneum, which, in g reflected from this organ in different directions, forms duplica-, named the *false ligaments* of the bladder.

he *inferior* or *pubic surface* is entirely destitute of peritoneum, and apposition with the *recto-vesical fascia*, the symphysis and body he pubis, and, if the organ be full, the lower part of the anterior wall he abdomen. It is connected to these parts by loose areolar tissue, to the back of the pubis by two strong bands of the recto-vesical ia, named the *anterior true ligaments*. This surface of the bladder be punctured above the pubis without wounding the peritoneum.

he *superior* or *abdominal surface* is entirely free, and covered every-re by the peritoneum, which in the male is prolonged also for a short ance upon the base of the bladder. In the male, this surface is in tact with the rectum, and in the female with the uterus, as well as, both sexes, with convolutions of the small intestine. Beneath the itoneum, in the male, a part of the vas deferens is found on each side he hinder portion of this surface.

he *summit* is connected to the anterior abdominal wall by a tapering lian cord, named the *urachus*, which is composed of fibrous tissue, ed at its base with plain muscular fibres which are prolonged upon it n the bladder. This cord, becoming narrower as it ascends, passes rards from the apex of the bladder between the linea alba and the itoneum, to reach the umbilicus, where it becomes blended with the e fibrous tissue found in that situation.

he urachus, which forms in the early fœtal state a tubular communication ween the urinary bladder and the allantoic vesicle, preserves, according to chka, vestiges of its original condition in the form of a long interrupted ity, with irregularities and dilatations, lined with epithelium similar to that he bladder, and sometimes communicating by a fine opening with the vesical ity.

he *sides* of the bladder, when it is distended, are rounded and pro-ent, and are each of them crossed obliquely by the cord of the terated hypogastric artery, which is connected posteriorly with the erior vesical artery, and runs forwards and upwards to the umbilicus, roaching the urachus above the summit of the bladder. Behind and re this cord the side of the bladder is covered with peritoneum, but w and in front of it the peritoneum does not reach the bladder, ch is here connected to the sides of the pelvic cavity by loose areolar ue containing fat, and, near its anterior and lower part, by the broad ansion from the recto-vesical fascia, forming the *lateral true ligament*.

vas deferens crosses obliquely the hinder part of this lateral surface, a before backwards and downwards, and turning over the obliterated ogastric artery, descends on the inner side of the ureter, along the r part of the superior surface, to the base of the bladder.

he *base* or *fundus* (fig. 578) is the widest part of the bladder. It is

directed downwards as well as backwards, and differs accor
the sex in its relations to other parts. In the *male* it rests aga
second portion of the rectum, and is covered superiorly for a sho
by the peritoneum, which, however, is immediately reflected
upon the rectum, so as to form the *recto-vesical pouch* (fig.
Below the line of reflection of the serous membrane, the base

Fig. 578.

Fig. 578.—Base or
BLADDER WITH THE
SEMINALES, VASA DE
AND PROSTATE GLA
Haller). ½.

a, line of reflection
toneum in the rec
pouch; *b*, the part
from which the perito
been removed, exposing
tudinal muscular fibre
vas deferens ending in
ejaculatory duct; *s*, le
seminalis joining the
the right vas deferens
right vesicula seminal
s, *s*, unravelled, are al
p, under side of the
gland, cut so as to e
ejaculatory ducts; *m*,
of the membranous por
urethra; *u*, *u*, the
which the right is turn
side.

bladder is adherent to the rectum by dense areolar tissue over a tr
area bounded at the sides by the vasa deferentia and vesiculæ s
(fig. 578 *s*, *s*), whilst its apex in front reaches the prostate gland
is in this space, which in the natural state of the parts is by no
large as it appears after they are disturbed in dissection, that the
may be punctured from the rectum without injury to the per
In the *female*, the base of the bladder is of less extent, and
reach so far back in the pelvis as in the male: for it rests ag
front of the neck of the uterus and the anterior wall of the vag
of which organs intervene between it and the rectum. This p
bladder adheres to the vagina, and above that adhesion the pe
forms a pouch between it and the uterus, much shallower than
vesical pouch of the male.

That part of the bladder where the urethra leads off from t
is the most strongly muscular part of the vesical wall, a
male it is closely connected with the base of the prostate
which it is supported. In both sexes this part of the bladd
erect posture is lowest; it lies at the angle of junction of the
the pubic surface.

Ligaments of the bladder.—The *true ligaments* of the bla
in number, two anterior and two lateral, all derived from t
portion of the recto-vesical fascia, have been already noticed.

The *false ligaments* or *peritoneal folds* are described as five i
Two of them, named posterior false ligaments or recto-vesical

rds in the male along the sides of the rectum to the posterior and l aspect of the bladder, and bound the sides of the recto-vesical -sac. In the female these posterior folds pass forwards from the of the uterus, and are comparatively small. The two *lateral* false nts extend from the iliac fossæ to the sides of the bladder, each ted from the corresponding posterior ligament by a prominent in which the obliterated hypogastric artery lies. The *superior* ligament (ligamentum suspensorium) is the portion of peritoneum en the ascending parts of the hypogastric arteries, and reaches the summit of the bladder to the umbilicus.

terior of the bladder.—On opening the bladder, its internal ce is found to be lined by a smooth membrane, which is compara- loosely attached to the other coats, so that in the empty condition e organ it is nearly everywhere thrown into small wrinkles or rugæ, l disappear as soon as the bladder is distended. Besides these, the ior of the bladder is often marked by reticular elevations or ridges, sponding with fasciculi of the muscular coat.

the lower part of the bladder is seen the orifice leading into the ra, around which the mucous membrane is corrugated longitudinally. ediately behind the urethral opening, at the lower part of the fundus, mooth triangular surface, having its apex turned forwards, which, g to the firmer adhesion of the mucous membrane to the subjacent s, never presents any rugæ, even when the bladder is empty. This ce is named the *trigone* (trigonum vesicæ, Lieutaud); at its poster- ior angles are the orifices of the two ureters, situated about an inch half from each other, and nearly the same distance from the anterior , where the bladder opens into the urethra.

e orifices of the ureters, presenting the appearance of oval slits, directed obliquely forwards and inwards: they are united by a d elevation, convex forwards, which extends generally outwards backwards beyond them, and which corresponds in position with scular band which joins them together and to the neck of the der. Proceeding forwards from opposite the middle of this, is ler slight elevation of the mucous surface, named the *uvula vesicæ* h projects from below into the urethral orifice. In the female, rigone is small, and the uvula indistinct. In the male the uvula little in advance of the middle lobe of the prostate, and is some- prolonged on the floor of the prostatic portion of the urethra. produced by a thickening of the submucous tissue. In its natural this may contribute to the more perfect closure of the orifice of ladder; when enlarged by disease it frequently produces considerable uction at the commencement of the urethra.

STRUCTURE OF THE BLADDER.

e bladder is composed of a *serous*, a *muscular*, a *submucous*, a *mucous* coat, and supplied with numerous blood-vessels and s.

e **serous or peritoneal coat** is a partial covering, investing only osterior and upper half of the bladder, and reflected from it upon rrounding parts in the manner already described in detail.

e **muscular coat** consists of unstriped muscular fibres, so arranged warrant the usual description of them as forming layers, the outer

of which consists of bundles of fibres more or less longitudinal, next of fibres more circular in disposition ; while beneath this, is imperfect longitudinal layer more recently recognised.

The *external* or *longitudinal fibres* (fig. 579, *a*, 580, *b*, and fig. 5 are most distinctly marked on the anterior and posterior surfac bladder. Commencing in front at the neck of the organ, from t

Fig. 579.

Fig. 580.

Fig. 579.—View of the muscular fibres of the bladder from beh Thomson, after Pettigrew, and from nature). ½

On the right side the superficial fibres are shown ; on the left the deep fibres chiefly are displayed. *a*, on the right side, the median and most superf of the longitudinal fibres, in which a slight decussation of fibres is seen ; diverging somewhat ; *a''*, the lowest, which pass much more obliquely ; the of the longitudinal fibres to the prostate is shown ; on the left side, *c*, the up middle, *c''*, the lowest set of circular or deeper fibres ; at *s*, the thickest and verse sets of these fibres forming the sphincter ; *p*, half the prostate left side, the left having been removed ; *u*, the urachus, into which some of the fibres are seen prolonged.

Fig. 580.—View of the muscular fibres of the bladder from behin (Thomson, after Pettigrew, and from nature). ½

On the right side the superficial fibres are displayed ; on the left the dee the same kind or intermediate fibres, and some of the circular fibres ; *b*, *b*, most superficial and strongest bands of longitudinal fibres on the right side ; diverging set of fibres near the middle of the bladder ; *b''*, the most div which surround the entrance of the ureters ; on the left side, *c*, *c'*, and *c''*, deeper circular fibres passing round at various levels and crossing with the de ing fibres posteriorly ; *s*, the most transverse fibres at the neck forming the *u*, the urachus ; *ur*, the ureters ; the left half of the prostate has been rem the sphincter ; *v*, part of the right vas deferens and vesicula seminalis.

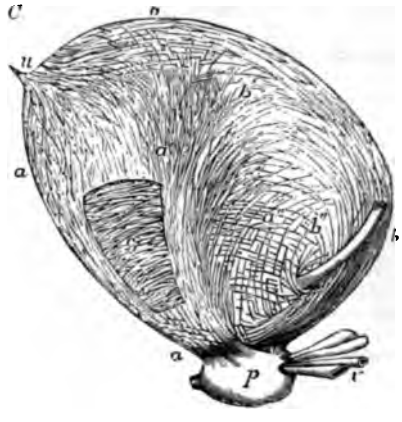
in both sexes (musculi pubo-vesicales), and, in the male, from t ing part of the prostate gland, they may be traced upwards anterior surface to the summit of the bladder ; and they may l followed down over the posterior surface and base to the und the neck of the bladder, where they become attached to the p the male, and to the front of the vagina in the female. Upon

icial fasciculi run more or less obliquely, and often intersect
er: in the male they reach the prostate. At the summit
: continued along the urachus. The longitudinal fibres
ether, constitute what has been named the *detrusor urinæ*

-called *circular* fibres form a thin and somewhat irregular
l layer distributed over the body of the bladder, having
pearances in different bladders. Their course may in general
upon as transverse, but for the most part throughout the
-thirds of the bladder they cross one another in very oblique
wards the lower part of the organ they assume a more circular
d upon the fundus and trigone form a tolerably regular layer.
nd around the cervix, in immediate connection with the pro-
he male, they densely encircle the orifice and constitute what
named the *sphincter vesicæ*, which, however, is not distinct from
fibres, and according to Henle does not perform the function
cter but can only serve to complete the evacuation of this part
lder, the part of a sphincter being performed by the muscular
he prostate.

ird stratum of fibres, still more deeply situated, and which
termed internal longitudinal, was first described by Ellis, who

Fig. 581.



-VIEW OF THE MUSCULAR F THE BLADDER FROM THE (Allen Thomson, after Petti- from nature). ½

ior and posterior superficial en running from below up- ing each other by their diver- side of the bladder, and are r the same letters as in the ures; at *c*, a portion of the gitudinal fibres has been re- to expose the deeper circular

hed it as "submucous." , and its bundles have r arrangement but with l longitudinal direc-

cular coat of the bladder forms so irregular a covering, that, when the ach distended, intervals arise in which the walls are very thin; and, internal or mucous lining protrude in any spot through the muscular sort of hernia is produced, which may go on increasing, so as to form lled a vesical sacculus, or *appendix vesicæ*, the bladder thus affected ed *sacculated*. Hypertrophy of the muscular fasciculi, which is liable stricture of the urethra or other affections impeding the issue of the rise to that condition named the *fasciculated* bladder, in which the the organ is marked by strong reticulated ridges or columns, with depressions.

the muscular coat, between it and the mucous membrane, but re intimately connected with the latter, is a well-marked layer tissue, *the vascular or* **submucous coat.** This submucous

areolar layer contains a large number of fine coiled fibres of elastic tissue.

The **mucous membrane** of the bladder is soft, smooth, and of a pale rose colour. It is continuous above with the lining membrane of the ureters and kidneys, and below with that of the urethra. Neither here nor in the ureters is the mucous membrane provided with a muscularis mucosæ. It adheres loosely to the muscular tissue, and is thus liable to be thrown into wrinkles, except at the trigone, where it is always more even. It is covered with a stratified epithelium, similar to that of the ureters. The cells vary much in form according to the condition of the tension of the bladder, for in the distended organ they are flattened out so as to cover a larger surface, while in the empty condition of the bladder they are of less diameter and proportionately higher.

Vessels.—The *superior vesical arteries* proceed from the remaining pervious portions of the hypogastric arteries; in the adult they appear as direct branches of the internal iliac. The *inferior* vesical arteries are usually derived from the anterior division of the internal iliac. In the female the uterine arteries also send branches to the bladder. The neck and base of the organ appear to be the most vascular portions. The *veins* form large plexuses around the neck, sides, and base of the bladder; they eventually pass into the internal iliac veins. The *lymphatics* follow a similar course.

The **nerves** are derived partly from the hypogastric plexus of the sympathetic and partly from the sacral plexus of the cerebro-spinal system. The former are said to be chiefly distributed to the upper part of the bladder, whilst the spinal nerves may be traced more directly to its neck and base. According to Kimister, the nerves form a network immediately under the epithelium, from which filaments pass amongst the epithelium cells, where they end in special cells. Gangliated plexuses of nerves accompany the blood-vessels, and send branches both to these and to the muscular coat of the bladder (F. Darwin).

Recent literature of the bladder and ureters.—*Obersteiner* in Stricker's Handbook, 1871; *Daneffe u. v. Welter*, (portion of bladder) Mém-pres. à l'acad. roy. de méd., Bruxelles, 1872; *Jurié* in Wiener med. Jahrb. IV. 1873; *Egli* in Arch. f. mikr. Anat., IX. (glands in pelvis); *Paneth* in Wiener Sitzungsb., 74, 1876 (epithelium); *Weigert*, *Hofmann* in Virch. Arch. LXX., LXXII., 1877 (abnormalities of ureter); *Hofmann*, ibid. (capacity of bladder); *Hamburger*, in Arch. f. mikr. Anat., XVII; *Mayer*, in Virch. Arch. LXXXV. (ganglion-cells in ureter).

On the muscular arrangements of the bladder, see Ellis, in Trans. Med. Chir. Society, 1856, and Demonstrations of Anatomy; Pettigrew, in Phil. Trans. for 1866; Sabatier, Rech. anat. et phys. sur les appareils musculaires correspondants à la vessie et à la prostate dans les deux sexes, 1864; *Cadiat* in Gaz. méd. V., 1876 (sphincter vesicæ).

REPRODUCTIVE ORGANS.

I. IN THE MALE SEX.

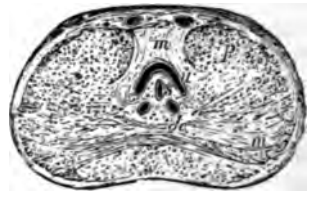
UNDER this head are included—1, the testes with their ducts and coverings; and, 2, the urethra, with certain accessory parts, such as the prostate and Cowper's glands. The urethra in the male is at once the outlet for the urine from the bladder and the products of secretion from the sexual glands. Extending from the neck of the bladder to the extremity of the penis, it is surrounded in its first part by the prostate gland, and there receives the excretory ducts of the testes and vesiculæ seminales; its second part passes through the triangular ligament of the perineum; and its third and longest part passes along the perineum and penis, surrounded by the corpus spongiosum.

THE PROSTATE GLAND.

The *prostate gland* is a firm, glandular, and muscular body, somewhat resembling a chestnut in shape and size, which adjoins the neck of the bladder, and encloses the first part of the urethra: it is placed in the pelvic cavity, on the upper aspect of the subpubic fascia, and rests anteriorly against the rectum. Its posterior or rectal surface is larger than its flattened anterior or pubic surface. It usually measures about an inch and a half across at its widest part, an inch and a quarter from base to its apex, and nearly an inch in thickness. Its ordinary weight is about six drachms.

The pubic surface of the prostate is flattened and marked with a slight longitudinal furrow; it is about half an inch or rather more from the pubic symphysis, and there, as well as at the sides, the gland is con-

Fig. 582.



582.—Transverse section of the prostate gland through the middle. (Allen Thomson.)

The urethra into which the eminence of the verumontanum rises from below; *s*, the sinus pocularis cut through; *d e*, the ejaculatory ducts; *m*, superiorly, the deep sphincter muscular fibres; *m*, lower down, intersecting muscular fibres in the lateral lobes of the prostate; *p*, prostatic glandular substance.

nected to the pubic bones by the thickenings of the pelvic fascia, which form the pubo-prostatic ligaments or anterior ligaments of the bladder. The posterior or rectal surface is smooth, and is marked by a slight depression, or by two grooves, which meet in front, and correspond with the course of the seminal ducts, as well as mark the limits of the lateral lobes in this situation: it is in close apposition with the rectum, immediately in front of the bend from the middle to the lower or anal part of that viscus, where the surface and superior border of the gland can be felt by the finger introduced into the intestine. The sides are convex and prominent, and are covered by the anterior portion of the levatores ani muscles, which pass back on each side, from the pubis and triangular ligament of the urethra, and embrace the sides of the prostate. The base of the gland directed towards the bladder is of considerable thickness, and is notched in the middle: its apex is turned towards the triangular ligament. As already stated, the prostate encloses the first part of the urethra. The canal runs nearer to the anterior than to the posterior surface of the gland, so that in general it is about a quarter of an inch distant from the former and about one-third of an inch from the latter; but it frequently varies greatly in this respect. The prostatic portion of the urethra is about an inch and a quarter long, and is dilated in the middle; it contains the colliculus seminalis and the openings of the seminal and prostatic ducts, as will be afterwards more particularly described. The common or ejaculatory seminal ducts, which pass forwards from the vesiculæ seminales, also traverse the lower part of the prostate, enclosed in a special hollow part of the gland, and open into the urethra; and in the middle, close in front of these, is the prostatic utricle.

The prostate is usually *described* as consisting of three lobes, two of

the superior layer of the triangular ligament. The
divisible into two layers, between which the prostati
enclosed (Adams). The glandular substance is ass
quantity of plain muscular tissue, which forms the p
stroma of the organ. This muscular tissue forms an
the fibrous capsule, and extends everywhere thro
substance: there is also a strong layer of circula
posteriorly with the sphincter vesicæ, and in front
surrounding the membranous part of the urethra.
prostate in front of the urethra is almost entirely
hinder part the muscular substance is in greatest
bladder.

The *glandular substance* is spongy and yielding; i
grey, or sometimes of a brownish hue. It consists of
alveoli, which unite into a smaller number of exc
epithelium is columnar throughout. According to
is a second layer of small cells next the basement
the tapered ends of the columnar cells. In the upp
the acini are smaller and more saccular; in the midd
the tubes are longer and convoluted at their ends. T
vessels form a close network as in other similar glan
acini, and the different portions of the gland are unit
and supported by processes of the deep layer of the f
by the muscular stroma. The ducts open by from
more orifices upon the floor of the urethra, chiefly in
side of the colliculus seminalis.

As age advances, this gland often becomes enlarged and
small round albumino-calcareous concretions of lamina
varying in size up to that of a millet seed.

Vessels and Nerves.—The prostate is supplied by bra
hæmorrhoidal, and pudic *arteries*. Its *veins* form a ple
fibrous covering round the sides and base of the gland, whi
in old subjects. These veins communicate in front with

THE PENIS.

The **penis** is composed principally of erectile tissue, arranged in three somewhat cylindrical masses, which are enclosed in fibrous sheaths, are united together so as to form a three-sided prism which receives covering from the general integument. Of these masses, two, named *corpora cavernosa penis*, placed side by side, form the principal part of organ, whilst the other, situated beneath the two preceding, surrounds canal of the urethra, and is named *corpus cavernosum urethræ* or *spongiosum*.

The penis is attached at its root to the symphysis of the pubes, and the pubic arch; in front it ends in an enlargement named the *glans*, which is structurally similar to and continuous with the corpus spongiosum. The intermediate portion or *body* of the penis, owing to the manner in which its three component parts are united together, has some somewhat flattened sides and three rounded borders: the upper one is named the *dorsum*. The *glans* penis, which is slightly compressed above and below, has at its extremity a vertical fissure forming the external orifice of the urethra; its base, which is wider than the body of the penis, is hollowed out to receive the narrowing extremities of the corpora cavernosa; its border is rounded and projecting, and is named the *corona glandis*, behind which is a constriction of the penis named the *cervix*. The median fold of integument connecting the glans below the urethral orifice to the inferior border of the penis is named the *frænum* of the prepuce.

The integument of the penis, which is continued from that of the pubes and scrotum, forms a simple investment as far as the neck of the glans. Here it is doubled up in a loose fold, the *prepuce* or *fore-skin*. The inner layer of this fold is firmly attached behind the cervix; and from thence the integument, becoming closely adherent, is continued forwards over the corona and glans, as far as the orifice of the urethra, where it meets with the mucous membrane of the urethra. Upon the body of the penis the skin is thin, free from fat, and, in the anterior two-thirds of its length, from hairs also; in these respects differing remarkably from that on the pubes, which is thick, covers a large cushion of fat, and, after puberty, is beset with hairs: the skin of the penis is moreover very movable and distensible, and is of a darker colour than that of the neighbouring parts. At the free margin of the prepuce the integument changes its character, and approaches that of a mucous membrane, being red, thin, and moist. Numerous sebaceous glands are collected round the cervix of the penis and corona glandis; they are named the *glands of Tyson*, or glandulæ odoriferæ, their secretion having a peculiar odour.

Upon the surface of the glans the integument again changes its character; it contains no glands, but is beset with large vascular and nervous papillæ, and it adheres most intimately and immovably to the spongy tissue of the glans.

Beneath the skin, on the body of the penis, the ordinary superficial fascia is very distinct; it is continuous with that of the groin, and also with the dartos tissue of the scrotum. Near the root of the organ there is in front a dense band of fibro-elastic tissue, named the *suspensory ligament*, lying amongst the fibres of the superficial fascia; it is triangular in form; its anterior border is free, above it is connected with the fore

part of the pubic symphysis, and below it runs down upon the dor
the penis.

The integuments of the penis are supplied with blood by branches
dorsal artery of the penis and external pudic; the veins join the dor
external pudic veins. Their nerves are derived from the dorsal and
superficial perineal branches of the pudic nerves.

THE CORPORA CAVERNOSA.

The **corpora cavernosa** form the principal part of the body
penis, and chiefly determine its form and consistence in the
erection. They are two cylindrical bodies, placed side by side, f
on their median aspects, and closely united and in part blended t
along the middle line in the anterior three-fourths of their
whilst at the back part, in contact with the symphysis pub
separate from each other in the form of two bulging and then t

Fig. 583.

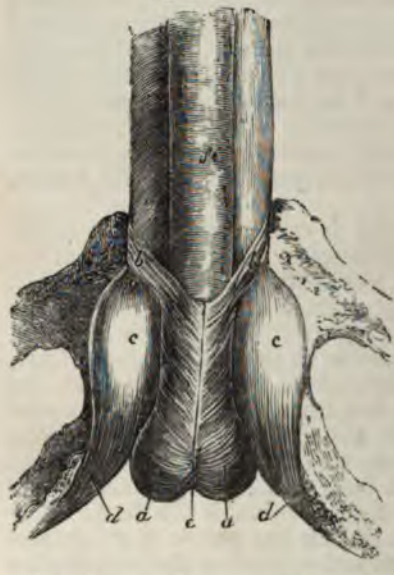


Fig. 583.—ROOT OF THE PENIS
TO THE RAMI OF THE PU
ISCHIUM (from Kobelt). ½

a, *a*, accelerator urinæ muscle
the bulb of the spongy bod
urethra, which presents at *c*, p
a median notch; *b*, *b*, anterio
the muscle or bulbo-cavernos
crura of the penis, presenting
dilatation or bulb of the corp
nosum; *d*, *d*, erectores penis m
corpus spongiosum urethræ.

processes named *crura*, wh
tending backwards, are a
to the pubic and ischia
and are invested by the e
penis or ischio-cavernosi
The enlarged portion at t
named by Kobelt the *bul*
corpora cavernosa, attains
greater proportionate
ment in some quadrupe
in man. In front, the
cavernosa are closely b
gether into a blunt conical extremity, which is covered by t
penis and firmly connected to its base by fibrous tissue.

The under surface of the united cavernous bodies presents
tudinal groove, in which is lodged the corpus spongiosum. Th
or anterior surface is also marked with a slight median groove
the dorsal vein of the penis is situated, and near the root is att
the pubes by the suspensory ligament.

Structure.—The median septum between the two corpora c
is thick and complete near the root of the penis; but farther fo
becomes thinner, and only imperfectly separates their cavitie
exhibits, particularly towards the anterior extremity, numerou
extending from the dorsal to the urethral edge, and admitti
free communication between the erectile tissue of the two sides.
the direction of these slits, the intermediate white portions of the

ble somewhat the teeth of a comb, and hence the partition has ed the name of *septum pectiniforme*.

external fibrous investment of the cavernous structure is white ense, from $\frac{1}{24}$th to $\frac{1}{12}$th of an inch thick, and very strong and

Fig. 584.

4.—TRANSVERSE SECTION OF THE PENIS IN THE DISTENDED STATE (altered from Henle).

outer outline indicates the integument sur- g the deeper parts; the erectile tissues of the cor- vernosa and the septum pectiniforme are shown on; *u*, placed on the section of the spongy body, he urethra; *v*, the single dorsal vein; *a*, the rtery, and *n*, the nerve of one side.

. It is composed for the most part of udinal bundles of shining white fibres, numerous well-developed elastic fibres, ing the two corpora cavernosa in a common covering; and internal s, each corpus cavernosum is surrounded by a layer of circular which enter into the formation of the septum.

n the interior of the fibrous envelope, and from the sides of the , numerous lamellæ, bands, and cords, composed of fibrous elastic ain muscular tissue, and named *trabeculæ*, pass inwards, and run h and across the cavity in all directions, thus subdividing it into titude of interstices, and giving the entire structure a spongy ter.

trabeculæ, whether lamelliform or cord-like, are larger and er near the circumference than along the centre of each cavernous and they also become gradually thicker towards the crura. The aces, conversely, are larger in the middle than near the surface;

Fig. 585.

5.—PORTION OF THE ILE TISSUE OF THE S CAVERNOSUM MAG- D, SHOWING THE AREO- STRUCTURE AND THE LAR DISTRIBUTION J. Müller).

mall artery supported larger trabeculæ, and g out on all sides; *c*, ril-like arterial tufts ne arteries of Müller; eolar structure formed ner trabeculæ.

ong diameter is, latter situation, transversely to the penis: and ecome larger to- he forepart of the They are occu- y venous blood, reality large cavernous veins, and are lined by a layer of flattened um similar *to that lining other* veins.

The intertrabecular spaces thus form a labyrinth of intercom
cating venous areolæ divided by the trabecular tissue, and
freely from one corpus cavernosum to the other through the
especially in front. The blood is carried away from these spaces
sets of veins, the one set joining the prostatic plexus and p
veins ; the others passing into the dorsal vein. Of these last so

Fig. 586.

$\frac{10}{1}$

Fig. 586.—PART OF A SECTION OF ONE OF THE CORPORA CAVERNOSA, INJECTED
DEEP ARTERY OF THE PENIS (Henle).

On the left is seen the fibrous tissue ; at *, a section of the arteria profunda

from between the corpus cavernosum and the spongy body of the
encircling the penis nearly at right angles, while others pa
directly into the dorsal vein from the upper surface.

The principal arteries of the corpora cavernosa are the ca

Fig. 587.

Fig. 587.—HELICINE ARTER
THEIR SHEATHS, &c. (from
MAGNIFIED WITH A LOW POWE

A and B, from the corpus ca
penis ; D, from the corpus sp
urethræ ; C, transverse section
the helicine arteries ; in this
other figures the smaller la
longations of the arterial vesse
sheath are shown ; * *, fascic
nective tissue passing off from
mit of two of the sheaths.

branches of the pudic
(profundæ penis), of t
and left sides ; but th
artery of the penis s
small twigs through th
sheath of the corpora
along the upper surface,
in the fore part of t
Within the cavernous
numerous branches of a
supported by the trabecu
middle of which they
terminate in branches
lary minuteness which open into the intertrabecular spaces ;
the arterial twigs projecting into the spaces, and forming

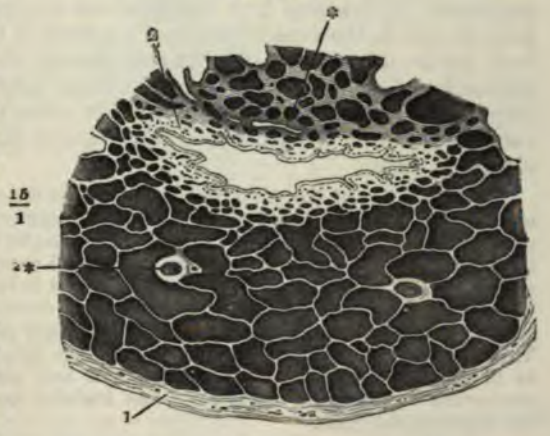
and somewhat dilated vessels, which were named by J. Muller, arteries. These are usually bound down by small fibrous bands 87,* *), and it appears to be due to this circumstance that these ing vessels acquire a looped or tortuous aspect when distended njection.

helicine arteries are most abundant in the posterior part of the corpora sa, and are found in the corresponding part of the corpus spongiosum ut they have not been seen in the glans penis. They are more distinct in man subject than in animals, where they are often missed. Small capillary es pass from them to supply the tissue of the enclosing sheath.
ddition to the blood which passes into the venous spaces from the y network of the sheath and trabeculæ some small arteries are said by er to open directly into the larger venous spaces.

CORPUS SPONGIOSUM.

corpus spongiosum urethræ commences in front of the tri- r ligament of the perineum, where it is placed between the diverging of the corpora cavernosa, and somewhat behind their point of junc- The enlarged and rounded posterior extremity is named the *bulb*, situated below the urethra. It extends forwards as a cylindrical, or y tapering body, lodged in the groove on the under side of the united

Fig. 588.



.—SECTION OF THE S SPONGIOSUM IN- D FROM ITS ARTERY e).

rous tunic of the cavernosum ; 2, membrane of the * Section of a of the mucous ne ; * * section of y.

ous bodies, as their blunt anterior ex- y, over which it ls so as to form ns penis already ed. In the of this extent ses the urethra.

posterior bulbous part, or *bulb of the urethra*, varies in size in nt subjects. It receives an investment from the triangular liga- on which it rests, and is embraced by the accelerator urinæ, or cavernosus muscle. The posterior extremity of the bulb exhibits, r less distinctly, a subdivision into two lateral portions or lobes, ted by a slight furrow on the lower surface, and by a slender partition within, which extends for a short distance forwards ; in infancy this is more marked. It is above this part that the a, having pierced the triangular ligament, enters the bulb, nded obliquely by a portion of the spongy tissue, named by Kobelt *liculus bulbi*, from which a layer of venous erectile tissue passes pon the membranous and prostatic portions of the urethra to the

are smaller, more uniform, and directed for the
their long diameter in the line of that of the peni
the meshes are smallest and most uniform. Plain
immediately surround the canal of the urethra, and
the external coat of the spongy substance. A c
derived from the internal pudic enters the bulb o
supplies the greater part of the spongy body, sen
far as the glans penis, but this part is chiefly supp
from the arteria dorsalis. Besides these, there is a
smaller branch of the pudic artery, entering the b
surface, about an inch from its posterior extrem
forwards in the corpus spongiosum to the glans (Kobe
open into the venous spaces chiefly if not entirely by t
capillaries. Veins issue from the glans and adjoining
body, to end in the vena dorsalis penis ; those of the
body for the most part pass backwards through the bu
prostatic and pudic venous plexuses : some emerge
corpora cavernosa, anastomose with their veins, and
cutaneous veins of the penis and scrotum, and partly
obturator veins.

The **lymphatics** of the penis form a dense network on t
and prepuce, and also underneath the mucous lining of the
chiefly into the inguinal glands. Deep-seated lymphatics
issuing from the cavernous and spongy bodies, and passing
with the deep veins, to join the lymphatic plexuses in the pe

The **nerves** of the penis are derived from the dorsal and
branches of the *pudic nerve* and from the *hypogastric plexus*
The former are distributed to the skin and mucous membran
to the cavernous and spongy bodies. Simple and compou
numerously on the nerves of the penis, and Pacinian bodies
the nerves of the glans.

URETHRA OF THE MALE.

The male urethra extends from the neck of th

plain muscular fibres, the inner fibres disposed longitudinally, and the er in a circular direction. The urethra is described under the three isions of the *prostatic*, *membranous*, and *spongy* portions.

Fig. 589.

Fig. 589.—THE LOWER PART OF THE BLADDER AND THE PROSTATIC, MEMBRANOUS, AND BULBOUS PARTS OF THE URETHRA OPENED FROM ABOVE. (Allen Thomson.)

A portion of the wall of the bladder and the upper part of the prostate gland have been removed, the corpora cavernosa penis have been separated in the middle line and turned to the side, and the urethra has been slit up; the bulb is left entire below, and upon and behind it the glands of Cowper with their ducts have been exposed. *t*, placed in the middle of the trigonum vesicæ; *u*, *u*, oblique apertures of the ureters; from these an elevation of the wall of the bladder is shown running down to *u v*, the uvula vesicæ; *l*, the longitudinal muscular fibres of the bladder passing down upon the prostate; *s v*, the circular fibres of the sphincter; *p*, the glandular part of the prostate; *p'*, the prostatic portion of the urethra; from the uvula vesicæ a median ridge is seen descending to the caput gallinaginis, in which *s* indicates the opening of the prostatic utricle, and *d*, that of one of the ejaculatory ducts; *m*, the commencement of the membranous portion of the urethra; *b*, the bulb of the spongy body; *b'*, the bulbous part of the urethra; *c*, one of Cowper's glands; *c d*, *c d*, course and orifice of its duct lying upon the bulb, and passing forward between the spongy body and the urethra, into which along with its fellow it opens; *c c*, one of the *corpora cavernosa*.

1. The first, or **prostatic portion,** is the part which passes through the prostate gland. It is about 1¼ inches in length, is the widest part of the canal, and is wider in the middle than at either end: at the neck of the bladder its diameter is nearly one-third of an inch, in the next part it widens a little, so as to be rather more than this (in old persons nearly half an inch), farther on it diminishes, until, at its anterior limit, it is smaller than at its commencement. It passes through the upper part of the prostate, above the middle lobe. Though enclosed in the firm glandular substance, it is more dilatable than any other part of the urethra; but immediately at the neck of the bladder, it is much more resistant. The transverse section of the urethra, as it lies in the prostate, is slightly curved with the convexity upwards.

The lining membrane of the prostatic portion of the urethra is thrown into longitudinal folds, when not distended by fluid. Towards the neck of the bladder, a slight elevation on the lower surface passes back into the uvula vesicæ. Somewhat in advance of this, and continued from it along the floor of the passage, projects a narrow median ridge, about three quarters of an inch in length, and one eighth of an inch in its greatest height; this ridge gradually rises into a peak, and sinks down again at its anterior or lower end, and is formed by an elevation of the mucous membrane and subjacent tissue. This is the crest of the urethra (crista urethræ), which also receives the names of *colliculus seminalis*, *caput gallinaginis* and *verumontanum*. On each side of this ridge the surface is slightly depressed, so as to form a longitudinal groove, named the *prostatic sinus*, the floor of which is pierced by numerous foramina, the orifices of the prostatic ducts. Through these a viscid fluid comes out on pressure; the ducts of the middle lobe open behind the urethral crest, and some others open before it. The prostatic urethral mucous membrane is covered by a laminated epithelium like that of the bladder.

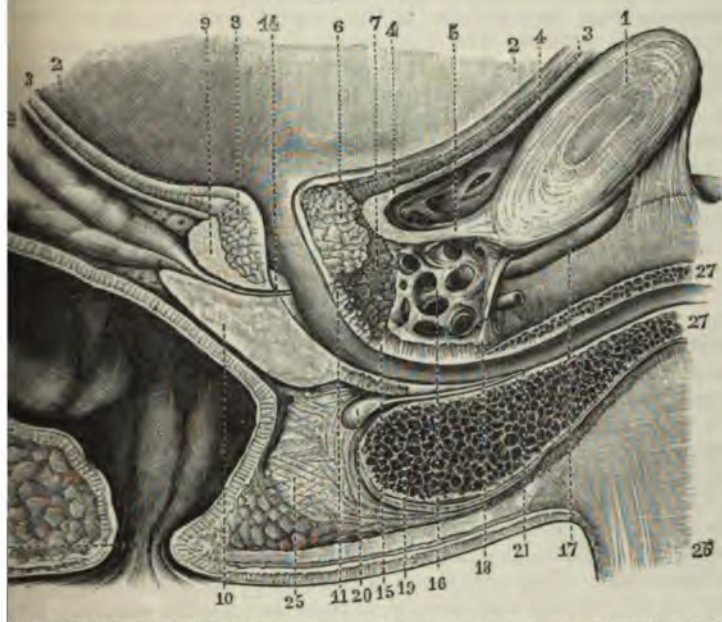
At the fore part of the most elevated portion of the crest, and exactly in the middle line, is a recess, upon or within the margins of which are placed the slit-like openings of the common seminal or ejaculatory ducts, one at each side. This median depression leads into the prostatic vesicle, which has been named also *sinus pocularis*, *utricle* or *uterus masculinus*. It was first described by Morgagni, and corresponds with the uterus in the female.

The vesicle forms a cul-de-sac running upwards or backwards, from three to five lines deep, and usually about one quarter to nearly half an inch wide at its entrance and for some distance up, but acquiring a width of at least one twelfth of an inch at its further end or fundus. The narrow portion runs in the urethral crest, and its fundus lies behind and beneath the middle lobe, and between the two lateral lobes of the prostate. Its parietes, which are distinct, and of some thickness, are composed of fibrous tissue and mucous membrane, together with a few muscular fibres, and enclose on each side the ejaculatory duct; numerous small ramified and convoluted glands open on its inner surface. The epithelial lining is of the laminated kind. The caput gallinaginis contains some well-marked erectile and plain muscular tissue, and it has been supposed that this eminence, when distended with blood, may offer an obstacle to the passage of the semen backwards into the bladder.

2. The **membranous portion** of the urethra comprises the part between the apex of the prostate and the bulb of the corpus spongiosum. It is three quarters of an inch long, but about half an inch of its posterior

is covered by the bulb of the corpus cavernosum which projects
rds over it. This membranous portion is the narrowest division
urethra. In the middle its diameter is one-fifth of an inch : at
d not quite so much. It is placed beneath the pubic arch, the
or concave surface being distant nearly an inch from the bone,
g an interval, occupied by the dorsal vessels and nerves of the
by areolar tissue, and some muscular fibres. Its lower convex
e is turned towards the perinæum, opposite the point of meeting

Fig. 590.



590.—SAGITTAL SECTION OF THE COMMENCEMENT OF THE URETHRA PASSING A LITTLE TO THE LEFT OF THE MIDDLE LINE (Sappey).

Symphysis pubis; 2, bladder; 3, 4, section of its wall; 5, pubo-prostatic ligament; 11, different parts of the prostate; 12, left vas deferens; 13, left seminal vesicle; culatory duct, opening on the veru montanum; 15, wall of the membranous part urethra; 16, areolar tissue with venous plexus, into which the vena dorsalis 17, is seen passing: 18, triangular ligament; 19, bulb of the corpus spongiosum; wper's gland; 21, its duct; 22, cavity of the rectum; 23, its walls; 24, anus; reolar and muscular tissue lying between the rectum and bulb; 26, septum ; 27, corpus spongiosum urethræ.

e transverse muscles; it is separated by an interval from the last of the rectum. About $\frac{1}{12}$th of an inch in front of the prostate erges from between the anterior borders of the levatores ani, and s through the deep layer of the subpubic fascia; it then lies between and the anterior layer (triangular ligament) through which it s someway farther forwards. Both these fibrous membranes are nged upon it, the one backwards and the other forwards. Between two layers the urethra is surrounded by erectile tissue, by some , and also by plain muscular tissue, whilst the fibres of the *compressor ræ* muscle are beneath it. On each side are Cowper's glands.

diameter, being intermediate in this respect betwe
membranous portions. The cross section of its canal
verse slit. The canal of the urethra in the glans h
when seen in a cross section, the form of a vertic
which is from one-third to half an inch in length,
considerably dilated, forming what is named the *fossa*

Lastly, at its orifice, which is a vertical fissure fr
inch in extent, and bounded by two small lips, the u
tracted and reaches its narrowest dimensions. From
of the tissues at its margin, this opening does not ad
or catheter as even the membranous portion of the ca

The **mucous membrane** of the urethra possesses
lium, of which the superficial cells are long and col
short distance (5 to 8 mm.) from the orifice, where the
where the subjacent membrane is beset with papill
rests on a basement membrane. Outside the mucous
a layer of convoluted vascular structure, and external
circular plain muscular fibres separating it from the
the spongy body.

The whole lining membrane of the urethra, except
beset with small racemose mucous glands and follicles
the *glands of Littré*, the ducts of which pass obliquel
the membrane. They vary much in size and in the ex
cavities are ramified and sacculated, some being quit
these there are larger recesses or *lacunæ*, opening
turned forwards, or down the canal. These are most
floor of the urethra, especially in its bulbous part.
spicuous recess, situated on the upper surface of the
named the *lacuna magna*. A median fold of the me
the inferior surface of this part of the urethra has bee
of the fossa navicularis.

Stratified concrements like those met with in the prostat

lobules held together by a firm investment. This latter, as the walls of the ducts, contains muscular tissue. The epithelium acini consists of clear columnar cells, with a reticular protoplasm, g like the cells of mucous glands. The ducts are lined with cubical ium. The ducts unite outside each gland to form a single ex- duct (fig. 589, *c d*). These ducts run forward near each other out an inch or an inch and a half, first in the spongy substance en beneath the mucous membrane, and terminate in the floor of lbous part of the urethra by two minute orifices opening obliquely. glands secrete a viscid fluid, the use of which is not known ; they to diminish in old age ; sometimes there is only one present, and id both may be absent.

sionally there is a third glandular body in front of and between Cowper's ; this has been named the *anterior prostate* or *ante-prostatic gland*.

muscles in connection with the urethra and penis have been y described with the muscles of the perinæum in the first volume.

ent Literature of the urethra and penis.—*Klein*, in Stricker's Handbook, 1871 ; *ger*, in Wiener Sitzungsb., XLVI. ; *Robin et Cadiat*, in Journ. de l'anat., 1875 use urethrale); *Langerhans*, in Virch. Arch., LXI. (accessory genital glands); *Iversen*, rd. med. ark. XI. (prostate) ; *M. v. Frey*, in Arch. f. Anat., 1880 (corpora sa) ; *Schneidemühl*, in Zeitschr. f. Thiermed., VI., 1880 (Cowper's glands).

E TESTES AND THEIR ACCESSORY STRUCTURES.

e *testes* or *testicles*, the two glandular organs which produce the atozoa, are situated in the pouch of integument termed the *scrotum*, being suspended by the *spermatic cord*.

e **spermatic cord**.—The parts which form this cord are the excre- luct of the testes, named the vas deferens, the spermatic artery and lymphatics, nerves, and connecting areolar tissue. Besides this he cord has several coverings in common with the testis. The ures mentioned come together to form the cord at the internal or abdominal ring, and, extending through the abdominal wall obliquely wards and towards the middle line, escape at the superficial or nal abdominal ring, whence the cord descends over the front of the into the scrotum.

e inguinal canal.—By the term inguinal canal is understood the occupied by the spermatic cord as it passes through the abdominal It extends from the deep to the superficial abdominal ring, and out an inch and a half in length. In the upper part of this course ord has the fascia transversalis behind it, and is covered in front by wer fibres of the internal oblique and transversalis muscles ; lower it lies in front of the conjoined tendon of these muscles, the fibres ich have arched inwards over it, and its cremasteric covering is in ct anteriorly with the aponeurosis of the external oblique muscle. inguinal canal is therefore said to be bounded posteriorly by the transversalis above and the conjoined tendon below, and anteriorly res of the transversalis and internal oblique muscles above, and the urosis of the external oblique muscle below ; while its floor is d by the curving backwards of Poupart's ligament, and its roof by pposition of the layers of the abdominal wall and the arched fibres internal oblique muscle.

it enters the inguinal canal, the cord receives a covering from the

infundibuliform fascia, a thin layer continuous with the fascia transversalis, and prolonged down from the margin of the deep abdominal ring; within the canal it receives a covering from the cremaster muscle and its layer of fascia; and as it emerges from the canal there is added superficially to this, the intercolumnar fascia prolonged from the margin of the superficial abdominal ring.

The scrotum.—The *scrotum* forms a purse-like investment for the testes and part of the spermatic cords. Its condition is liable to some variations according to the state of the health and other circumstances: thus it is short and corrugated in robust persons and under the effects of cold, but becomes loose and pendulous in persons of weak constitution, and under the relaxing influence of heat. A superficial division into two lateral halves is marked by a slight median ridge, named the *raphe*, extending forwards to the under side of the penis, and backwards along the perinæum to the margin of the anus.

The coverings of the cord and testis in the scrotum may be enumerated from without inwards as follows, viz., the *skin*, *superficial fascia* and *dartos tissue*, the *intercolumnar fascia*, the *cremaster muscle* and *fascia*, and the *infundibuliform fascia*, which is united to the cord by a layer of loose areolar tissue; lastly, the special serous membrane of the testis named the *tunica vaginalis*, which forms a close sac, of which one part lines the scrotum and the other closely envelopes the testis.

1. The **skin** of the scrotum is very thin, and is of a darker colour than elsewhere; it is generally thrown into rugæ or folds, which are more or less distinct according to the circumstances already mentioned. It is furnished with sebaceous follicles, the secretion from which has a peculiar odour, and it is covered over with thinly scattered curled and flattened hairs, the bulbs of which may be seen or felt through the skin when the scrotum is stretched. The superficial blood-vessels are also readily distinguished through this thin integument.

2. Immediately beneath the skin of the scrotum there is found a thin layer of a peculiar loose reddish-brown tissue, endowed with contractility, and named the **dartos tunic**. This subcutaneous layer is continuous with the superficial fascia of the groin, perinæum, and inner side of the thighs, but assumes a different structure, and is entirely free from fat. The dartoid tissue, which is more abundant on the fore part of the scrotum than behind, forms two distinct sacs, for the corresponding testes, united together along the middle line so as to establish a median partition named the *septum scroti*, which is adherent below to the deep surface of the raphe, and reaches upwards to the root of the penis. The dartos is very vascular, and owes its contractile properties to the presence of a considerable amount of unstriped muscular tissue (Kölliker).

3. The **intercolumnar** or **spermatic fascia**, a very thin and transparent but relatively firm layer, derived from the tendon of the external oblique muscle of the abdomen, is attached above to the margins of the external ring, and is prolonged downwards upon the cord and testis. It lies at first beneath the superficial fascia, and lower down beneath the dartos, and it is intimately connected with the layer next mentioned.

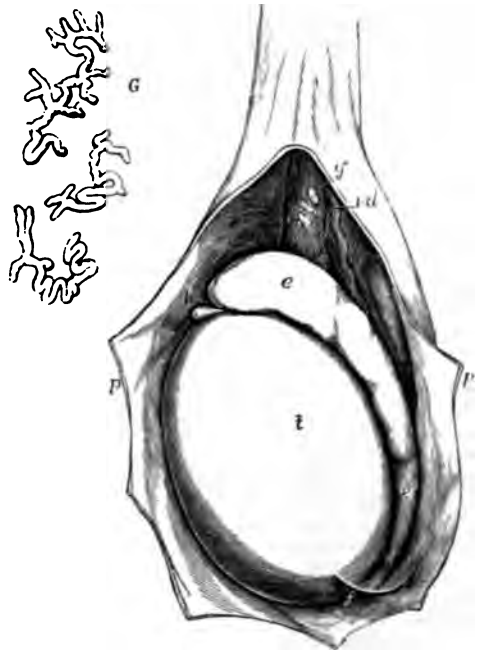
4. The **cremasteric** layer is composed of scattered bundles of striped muscular fibres, connected together into a continuous covering by intermediate areolar membrane. The red muscular portion, which is continuous with the lower border of the internal oblique muscle of the abdomen, constitutes the *cremaster muscle*, and the entire covering is

iasteric fascia. By the action of the cremaster the cord is the testicle is raised towards the body.

ndibuliform fascia, continuous above with the *fascia* nd the subperitoneal areolar membrane, and situated neath the cremasteric fascia, invests the cord completely, d below with the posterior part of the testicle and the f its serous tunic. On forcing air beneath the infundi-, a quantity of loose and delicate areolar tissue is seen to ep surface with the vas deferens and spermatic blood- form lamellæ between them. This areolar tissue is con- with the subserous areolar tissue found beneath the peri- anterior wall of the abdomen; below, it is lost upon the ticle. Together with the infundibuliform fascia, it forms *ia* of Astley Cooper.

this loose areolar tissue, in front of the upper end of the cord, n a fibrous band, which is connected above with the pouch of id opposite the upper end of the inguinal canal, and which s for a variable distance along the spermatic cord. Occasionally d as a fine cord, as far as the upper end of the tunica vaginalis; ce of it can be detected. It is the vestige of a tubular process m, which in the fœtus connects the tunica vaginalis with the

Fig. 591.



EFT TUNICA ED, SHOW- S, EPIDIDY- THE OUTER MSON.)

lges of the nalis drawn ly of the pididymis; unica vagi- the body side. In the figure s has been place of its rd to show ns, and *g*, ds; G, the es of this t ten times, remains of ithin them; agni.

al mem- e is placed en during of fœtal eriod con- its escape al cavity, eritoneum

down into the scrotum. Into this pouch, or *processus vaginalis* sticle projects from behind, supported by a duplicature of the , named the *mesorchium*. Sooner or later after the gland has e scrotum, the upper part or neck of this pouch becomes con-

tracted and finally obliterated, from the internal abdominal ring down
the testicle, leaving no trace but the indistinct fibrous cord already
while the lower part remains as a closed serous sac surrounding the
which is thence named the tunica vaginalis.

In the female fœtus an analogous pouch of peritoneum descends for
distance along the round ligamemt of the uterus, and has received the
tion of the *canal of Nuck*. Of this traces may almost always be seen in the

The neck of the processus vaginalis sometimes becomes closed at intervals
leaving a series of sacculi along the front of the cord; or a long pouch
continue open at the upper end, leading from the abdominal cavity
inguinal canal. In other instances, the peritoneal process remains
pervious, and the cavity of the tunica vaginalis is thus made continuous
that of the peritoneum. In such a case of congenital defect, a portion
intestine or omentum may descend from the abdomen into the inguinal
and scrotum, and constitute what is named a congenital hernia. Lastly,
both testes may remain permanently within the abdomen, or their descent
be delayed till after puberty, when it may occasion serious disturbance.
tion of the testes in the abdomen (cryptorchismus) is, in many instances
accompaniment of arrested development of the glandular structure;
however, a peculiarity which may be present without impotence.

In a few mammals, as the elephant, the testes remain permanently within
abdomen; in a much larger number, as the rodentia, they only descend
period of rut. The complete closure of the tunica vaginalis is peculiar to
and may be considered as connected with his adaptation to the erect posture.

6. The **tunica vaginalis.**—This tunic forms a shut sac, of which
opposite free surfaces are in contact with each other. Like the
membranes in general, of which it presents one of the simplest
it may be described as consisting of a *visceral* and a *parietal* portion.
The visceral portion, *tunica vaginalis testis*, closely invests the
part of the body of the testis, as well as the epididymis, between
parts it is depressed in the form of a pouch (digital fossa), and
their contiguous surfaces, and it adheres intimately to the proper
tunic of the gland. Along the posterior border of the gland, where
vessels and ducts enter or pass out, the serous coat, having been
flected, is wanting. This portion of the serous covering frequently
sents villous prolongations on the borders of the epididymis and
end of the testis; these processes, sometimes of considerable length,
covered in some places with cylindrical, in others with layers of
epithelium.

The parietal or scrotal portion of the tunica vaginalis is more extensive than
that which covers the body of the testis; it reaches upwards, sometimes for a
considerable distance, upon the spermatic cord, extending somewhat higher on
the inner than on the outer side. It also reaches downwards below the testis,
which, therefore, appears to be suspended at the back of the serous sac, when
this latter is distended with fluid; a fold, or so-called ligament, being left
projecting at the lower end of the epididymis (fig. 591, *f*).

Vessels and nerves of the scrotum and spermatic cord.—The arteries are
derived from several sources. Thus, the two *external pudic* arteries, branches of
the femoral, reach the front and sides of the scrotum, supplying the integument
and dartos; the *superficial perineal* branch of the internal pudic artery is distributed to the back part of the scrotum; and, lastly, more deeply seated than
either of these is a branch given from the epigastric artery, named *cremasteric*,
which is chiefly distributed to the cremaster muscle, but also supplies small
branches to the other coverings of the cord, and by its ultimate divisions anastomoses with the other vessels. The *artery of the vas deferens*, a long slender
vessel derived from the superior vesical, accompanies the tube in its whole
length. The veins accompany the arteries. The veins of the cord form the

r pampiniform plexus elsewhere described. The lymphatics pass uinal lymphatic glands.

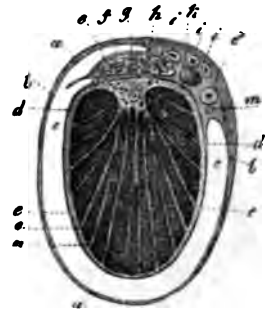
es also proceed from various sources. Thus, the *ilio-inguinal*, a ie lumbar plexus issuing by the external abdominal ring, supplies the of the scrotum; this nerve is joined also by a filament from the *ric* branch of the same plexus: sometimes two separate cutaneous forward through the external ring. The two *superficial perineal* the internal pudic nerve accompany the artery of the same name the inferior and posterior parts of the scrotum. The *inferior* branch of the small sciatic nerve, joins with the perineal nerves, and s distributed to the sides and fore part of the scrotum. Lastly, the *anch of the genito-crural* nerve reaching the spermatic cord at the ominal ring, passes with it through the inguinal canal, and supplies the cremaster muscle, besides sending a few filaments to the other ıgs of the cord and testicle.

THE TESTICLES.

tes, or principal reproductive glands (*διδυμος, ορχις*), are susiquely in the scrotum by means of the cord and membranes cribed; they are usually placed at unequal heights, that of being lower than the other. They are of an ovoid form, but y compressed laterally, so that they have two somewhat des or faces, an upper and a lower end, an anterior and a order. They are about an inch and a half long, an inch and ride from back to front, and nearly an inch thick from side to weight of each varies from three-quarters of an ounce to an left being often a little the larger of the two.

t and sides of the testis, together with the upper and the are free, smooth, and closely invested by the tunica vaginalis. or border is attached to the spermatic cord, and it is here ssels and nerves enter or pass out. When the testis is sus- its usual position, its upper end is directed obliquely forwards rds, as well as upwards, whilst the lower, which is rather the opposite direction. It follows from this that the postached border is turned upwards and inwards, and the outer ce slightly backwards.

Fig. 592.



RANSVERSE SECTION THROUGH THE ICLE AND THE TUNICA VAGINALIS (from

re tissue enveloping the parietal layer aginalis; *b*, this layer itself; *c*, cavity vaginalis; *d*, reflected or visceral layer , the tunica albuginea; *f*, covering of) on the right or outer side; *h*, medias- *i*, branches of the spermatic artery; rein; *l*, vas deferens; *m*, small artery ferens; *n*, *o*, septa or processes from um to the surface.

to the posterior border of the resting also on the neighrtion of its outer face, is a w body, the *epididymis*, which of the excretory apparatus of the testicle, and is prinposed of the *convolutions* of a long tortuous canal or

efferent duct, to be presently described. Its upper extre siderably larger than the lower, projects forwards on the up the testis, and is named the *head* or *globus major* (fig. 591, *e*); which is more pointed, is termed the *tail* or *globus minor* (*e'*); intervening portion is named the *body*. The convex surf epididymis and the thin anterior border are free, and cove tunica vaginalis. The concave surface, or that directed t testis, except at the upper and lower ends, is also free, and i the same tunic, which here forms the digital pouch between t mis and the outer face of the testicle, and nearly surrounds tl mis, except along its posterior border, which is united to th a duplicature of the serous membrane, containing numerous bl At its upper and lower extremity, the epididymis is attac testis by fibrous tissue and a reflection of the tunica vaginali major also by the efferent ducts of the testis.

At the back of the testis and epididymis, beneath the fas opposite the lower two-thirds of the testis, is a considerabl unstriped muscular tissue, the *inner muscular tunic* of Köllik

On the front of the globus major, somewhat to the outer si usually found one or more small pedunculated bodies co extension of the tunica vaginalis and formed mainly by conn and blood-vessels. These are the *hydatids of Morgagni*. Tl monly regarded as the remains of the fœtal structure tern duct. One of them of a more regularly pyriform shap constant than the rest, lies closely between the head of th and the testis.

This has been thought, but as it would appear on insufficient e the homologue of the ovary in the male sex (Fleischl, Krause). ciliated, and a canal lined by ciliated epithelium and opening into the tunica vaginalis is sometimes contained within it.

STRUCTURE OF THE TESTIS.—The testis is enclosed in a str the **tunica albuginea.** This is a dense unyielding fibrou of a white colour, and of considerable thickness, which immedi the soft substance of the testis, and preserves the form of th

Fig. 593.

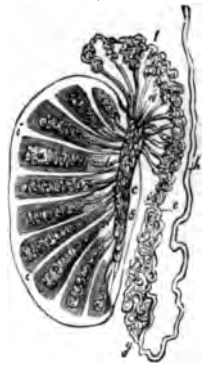


Fig. 593.—PLAN OF A VERTICAL SECTION OF SHOWING THE ARRANGEMENT OF THE

The true length and diameter of the ducts regarded. *a*, *a*, tubuli seminiferi coiled up lobes; *b*, vasa recta; *c*, rete vasculosum; *d*, ending in the coni vasculosi; *l*, *e*, *g*, conv the epididymis; *h*, vas deferens; *f*, sectio part of the tunica albuginea; *i*, *i*, fibrous ning between the lobes; *f* to *s*, mediastinum

is composed of bundles of fibrous t interlace in every direction. The out covered by the tunica vaginalis, e the posterior border of the testis, spermatic vessels pass through and tremities of the epididymis are attac

In the interior, the fibrous tis tunica albuginea is prolonged from the posterior border for tance into the substance of the gland, so as to form within

ertical septum, known as the *corpus Highmori*, and named by Cooper *mediastinum testis*. It extends from the upper nearly lower end of the gland, and it is wider above than below. The sue of which it is composed is traversed by a network of seminal and by the larger blood-vessels of the gland, which are lodged nels formed in the fibrous tissue.

n the front and sides of the corpus Highmori numerous slender cords and imperfect septa of connective tissue are given off in ng directions, and are attached by their outer ends to the internal of the tunica albuginea at different points, thus incompletely g the glandular substance into lobules. According to Kölliker, muscular fibres are prolonged upon these septula. The whole l surface of the tunica albuginea is covered by a multitude of fine ssels, which are branches of the spermatic artery and veins, and ld together by a delicate areolar web. Similar delicate ramifi- of vessels are seen on the various fibrous offsets of the medi- n, upon which the blood-vessels are thus supported in the interior gland. This vascular network, together with its connecting tissue, constitutes the *tunica vasculosa* of Astley Cooper.

glandular substance of the testis which is included in the fibrous ork formed by the albuginea, the mediastinum and the trabeculæ es of convoluted tubules known as the **tubuli seminiferi** which newhat loosely connected together by areolar tissue into the lobes les above mentioned. Of these lobes there are some 300 or 400 e); they are of unequal size, the middle ones being the larger; e imperfectly separated from one another, the septa being in- te. In each lobe are two, three or more seminiferous tubules convoluted, and here and there branched, especially at their r or distal extremity where, in a *cortical zone* near the albuginea, requently communicate laterally with one another. It is not t to unravel the tubules for some distance, for their walls are tely strong, and their diameter ($\frac{1}{100}$th to $\frac{1}{150}$th of an inch) large ed with those of other tubular glands, such as the kidney. Their is estimated to be on an average rather greater than two feet, eir number between 800 and 900 (Lauth). They have a contour, but this is interrupted at intervals by small bulgings, are more numerous near the commencement of a tubule than near nination. The walls of the seminiferous tubules are composed of layers of flattened cells. Of these only the innermost layer is te, being formed of epithelioid cells closely united edge to edge into nent membrane. This is strengthened by the other layers, which, r, exhibit intervals between the flattened cells which compose these intervals becoming very marked in the outermost layers. sequence of their being thus formed of several layers, the walls tubules have a concentrically striated appearance in cross-

tubules are occupied by an epithelium which consists of several ar layers of cells, amongst which the seminal filaments or tozoa may be observed in different stages of development (fig. In different tubules of the same testis and even in parts of the ubule the condition of development of the spermatozoa may be arious, and the epithelium presents corresponding differences the number of its layers and the appearance of the cells.

In all cases, however, there is a complete or tolerably regular cubical or somewhat flattened cells which immediately lines the l membrane. A few of these *outer* or *lining cells* usually present tions of proliferation, the nucleus being in one of the phases chara of division, and here and there one of these cells may project those of the next layer.

Within this stratum, in those parts where the formation of sper has progressed to its fullest extent (fig. 594, *c*), we come across gular layer of large clear rounded cells, many of which from the ap of their nuclei are undergoing proliferation. They may be ter

Fig. 594.

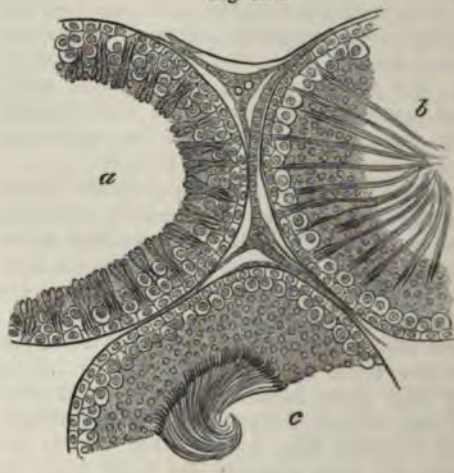


Fig. 594.—Section OF THREE SEMINIF BULES OF THE RA from a preparati A. Fraser). Mag

a, with the sp least advanced in ment; *b*, more adv containing fully spermatozoa. Bet tubules are seen s interstitial cells w vessels and lymph-s

intermediate or *rating cells.* Th bably give origi cells of the t *innermost* or *layer* which con a number of granular ill-defin which appear blended with one another into an almost uniform Their nuclei are small and faint, staining only slightly with l and do not show evidence of undergoing proliferation; towa lumen of the tubule they become very faintly outlined. Imbe the innermost part of this layer are the heads of the sperm whilst their tails project into and occupy the lumen of the tub rally being bent down and extending for a short distance al course.

It appears probable that the spermatozoa are set free by the breakin into an albuminous fluid of the protoplasmic layer in which their h imbedded. In those parts of the seminiferous tubules and ducts spermatozoa are free they are accompanied by nuclei and portions of substance, derived in all probability from the cells of this layer, the protoplasm of which may be supposed to serve for the nutrition spermatozoa.

In other tubules, from which the spermatozoa have recently be charged, the innermost layer is almost or entirely absent but th liferating cells are two, three, or more rows deep. The forma fresh spermatozoa appears to take place from some of these cells, of daughter-cells being formed by their proliferation, and each dau cell giving rise to a spermatozoon (fig. 594, *a*).

certain whether the lining-cells may not also produce spermatozoa; in-rding to some authorities, they alone are concerned in the process (see linee, however, in any case the lining cells by their proliferation have given rise to the cells of the next layer, and probably continue to do so e, the difference of opinion is not of so great importance as it at first r seem.

uclei of the cells which are concerned in the production of the oa (spermatoblasts) undergo division by the ordinary process of sis (see pp. 11 to 16) into two, four, or even more daughter-nuclei, which arate from one another at once, each with a proportionate amount otoplasm of the mother-cell, or remain for a time enclosed within the ll. From the daughter-nuclei the heads of the spermatozoa are deve-lle the tails are formed from the enclosing protoplasm, but the exact formation will be described after their structure has been treated of. onsequence of their development from a number of daughter-cells from the proliferation of a mother-cell that the arrangement into determined.

meantime the groups become more separated from one another ccumulation between them of cells of the third or nutritive hich appear also to be produced by the proliferation of some ntermediate cells. This is accompanied by a gradual shifting of ps of spermatozoa towards the lumen, but for some time many remain with the heads buried in the outermost part of the layer and even between the cells of the intermediate layer , *b*). Eventually, however, they become entirely accumulated lumen, where they are more closely packed and the arrange-to groups becomes in a large measure obscured (fig. 594, *c*). ifferent conditions of the epithelium of the tubules can often served in sections of adjacent tubules.

ve account of the appearances presented by the contents of the semini-bules, which is the result of a renewed investigation of the subject,* some respects from that of preceding writers. According to some ll the cells within the lining layer are spermatoblasts, the distinction these and cells which simply serve for their support and nutrition not ognized. According to most other authors, it is only the cells of the er which give rise to spermatozoa; some of these cells (spermatoblasts) growing towards the lumen between the cells of the inner layers as columns terminating in enlarged extremities. Within the latter the ultiply, and form daughter-nuclei, and from these and the protoplasm ng them the spermatozoa are developed, and are thus at first grouped at the extremity of the elongated columns. The cells between serve r support and nutrition. As has already been stated, this view is not y different from the one adopted in the text; differing chiefly from nsisting upon the permanent connection of the spermatoblasts with the ithelium.

iffers from most authors in describing the spermatozoa as becoming de-rom completely separated daughter-cells (fig. 595, A, B), and as possess-nt no grouped arrangement, this being subsequently acquired (fig. ut in what manner is not explained. As to this view it may be re-hat there is no doubt the grouping appears more distinct in intermediate development (as in fig. 594, *b*) than in the earliest stages; but that this be owing to the accumulation of nutritive cells between groups of cells, which are already existent, but which are at first so nearly in a that the eye fails to distinguish clearly the intervals between the groups.

e been much assisted in coming to a conclusion upon this question by the n of specimens which were placed at my disposal by Mr. A. Frazer, M. B., tor of Anatomy in Owens College. (E.A.S.)

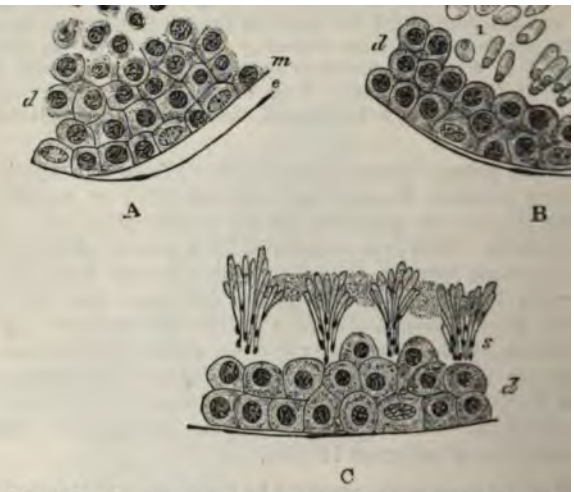


Fig. 595.—Stages in the development of the spermatozoa o

m, membrana propria; *d*, epithelium; *e*, lamina of connect
daughter cells in different stages of development into spermatozoa;
tozoa in groups.

Interstitial tissue, lymphatics, and blood-vess

which connects the seminiferous tubules is in some resp
consists of fine fasciculi and laminæ of areolar tissue, th
by and partly composed of flattened epithelioid cells. Be
and fasciculi are large cleft-like spaces, containing ly
everywhere enclosing the basement membrane of the t
spaces are injected by the puncture-method, the inje
away by the lymphatics of the spermatic cord. It is f
between the incomplete outer layers of the basement

uestion cannot be distinguished from the other cells of the
intertubular connective tissue. Similar cells are met with in
of the ovary.

pillaries form a close network over the walls of the semini-
ules.

of the testis.—As the convoluted tubuli seminiferi approach
stinum testis they unite, as before said, with one another at
es into a smaller number of tubes which have a less flexuous
d at length become nearly straight. Close to the mediastinum
into short, straight tubes (**tubuli recti**), of smaller diameter
than the seminiferous tubes, and differing from them in the character of their epithelium (fig. 596). This, in the straight tubules, is a single layer of flattened or cubical cells continuous with the outer or

Fig. 596.

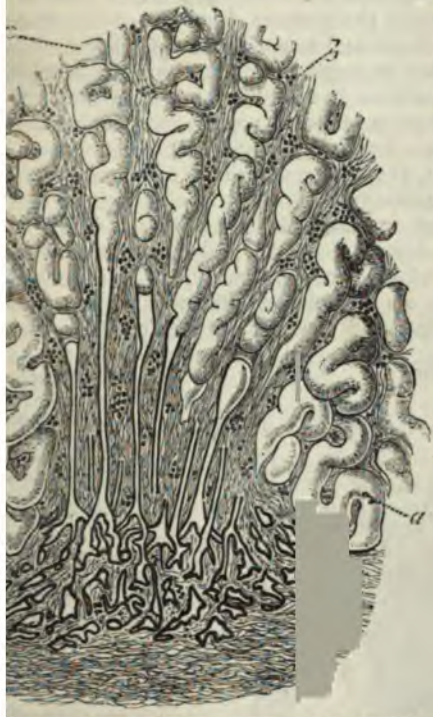


Fig. 597.

PASSAGE OF CONVOLUTED SEMINIFEROUS TUBULES INTO STRAIGHT TUBULES AND OF THESE INTO THE RETE TESTIS (Mihalkovics).
ferous tubules; *b*, fibrous stroma continued from the mediastinum testis;

97.—DUCTS OF THE TESTICLE INJECTED WITH MERCURY (from Haller).
the testicle; *b*, tubuli in the interior of the gland; *c*, rete vasculosum; *d*, tia terminating in the coni vasculosi; *e*, *f*, *g*, convoluted canal of the *h*, vas deferens ascending from the globus minor of the epididymis.

s of the seminiferous tubes. The basement membrane is also on to the straight tubules.

raight tubules open into a network of vessels which lies in ance of the mediastinum, and was named by Haller, **rete um testis** (fig. 596, *c*). The tubes composing the rete have walls, but are merely channels in the fibrous stroma, lined by

flattened epithelium. Their diameter is greater than that of th
recti. The secretion from the testis is accumulated in the rete
conducted to the upper and back part of the testis, whence it
veyed away by the **efferent tubules**, or **vasa efferentia**. T
from twelve to fifteen, or sometimes twenty in number; they
the tunica albuginea beneath the globus major of the epidi
which they may be said to form a part, and in the convoluted
which they ultimately terminate. On emerging from the tes
vasa efferentia are straight, but, becoming more and more conv
they proceed towards the epididymis, they form a series of smal
masses, the bases of which are turned in the same direction, and
named *coni vasculosi* (fig. 598, *f*). They are about $\frac{1}{30}$th of an
diameter. The largest of the cones is about two-thirds of an i
and when unrolled, each is found to consist of a single coiled duct
from six to eight inches in length, and the diameter of which
decreases from the testis to the epididymis (Huschke). Opp
globus major these separate efferent vessels open, at intervals
the unravelled tube, are found to be about three inches in len
a single canal or duct, the intervening and subsequent convol
which constitute the epididymis itself.

The **canal of the epididymis** (fig. 598, *g*) is disposed
numerous coils, and extends from the globus major downwar
globus minor or tail, where, turning upwards, it is continued
vas deferens. When its complicated flexuosities are unroll
found to be twenty feet and upwards in length. The small

Fig. 598.

Fig. 598.—INJECTED
DIDYMIS, AND VA
(from Kölliker afte

a, body of the test
bules; *c*, vasa recta;
culosum; *e*, vasa eff
coni vasculosi; *g*, epid
vas deferens; *i*, vas al
branches of the sperm
passing to the testicle
dymis; *n*, ramificati
testis; *o*, artery of t
ferens; *p*, its union w
of the spermatic artery

ings are supported
together by fine ar
sue; but, besides thi
ous incomplete, tr
fibrous partitions
posed between large
of the coils, whi
been named the *lob*
epididymis. The
the epididymis is
commencement, ab
of an inch in diam
diminishing as it
towards the globus minor, it is about $\frac{1}{10}$th of an inch, after which

ses in size, and becomes less deeply convoluted as it approaches the vas
ns. Its coats, which are at first thin, become thicker in its progress.
e vasa efferentia and the tube of the epididymis are provided with
siderable amount of plain muscular fibres in their wall. The
lial lining cells are columnar or prismatic in form and are ciliated,
lia being long, and causing by their movement a current in the
rd direction. In the epididymis the cells are greatly elongated, in
sa efferentia they are shorter ; in the lower part of the epididymis
lia disappear. Between the fixed ends of the columnar cells other
r cells are met with.

e **vas deferens** (fig. 598, *h*), or excretory duct of the testis, forms
ntinuation upwards of the convoluted canal of the epididymis. It
ences at the lower end of the epididymis, and, at first rather tortuous
fterwards becoming straight, it ascends upon the inner side of the
lymis, and along the back of the testicle, separated from both,
er, by the blood-vessels passing to and from the gland. Con-
g then to ascend in the spermatic cord, the vas deferens accom-
s the spermatic artery, veins and nerves, as far as the internal
minal ring. Between the testicle and the external ring its course is
vertical : it lies behind the spermatic vessels, and is readily dis-
ished by its hard cord-like feel. It then passes obliquely upwards
utwards along the inguinal canal, and reaching the inner border of
ternal abdominal ring, it leaves the spermatic vessels (which extend
lumbar region), and turns suddenly downwards and inwards into
elvis, crossing over the external iliac vessels, and turning round the
or iliac side of the epigastric artery. Running beneath the peri-
m, it reaches the side of the bladder (fig. 577, *i*), upon which it
nds, curving backwards and downwards to the hinder surface of
viscus, and finally passes forwards to the base of the prostate gland.
s course within the pelvis, it crosses over the cord of the obliterated
gastric artery, and lies to the inner side of the ureter. Beyond this
, where it ceases to be covered by the peritoneum, it is attached to
oats of the bladder, in contact with the rectum, and gradually
aching its fellow of the opposite side. Upon the base of the
er, the vasa deferentia are situated between two elongated
tacles, named the seminal vesicles (fig. 600) ; and, close to the base
e prostate, each vas deferens ends by joining with the duct from
rresponding seminal vesicle on its outer side to form one of the
on seminal or ejaculatory ducts (fig. 590, 14).

vas deferens measures nearly two feet in length. In the greater
f its extent it is cylindrical or slightly compressed, and has an
e diameter of about one-tenth of an inch ; but towards its termina-
eneath the bladder, it becomes enlarged and sacculated, forming
ampulla of Henle, and resembling in shape and structure a part of
minal vesicle. Previously to its junction with the duct of that
, it again becomes narrowed into a smaller and straight cylindrical

The walls of the vas deferens are very dense and strong, and feel
o the touch, owing to the large proportion their thickness bears to
ner cavity of the tube, which is scarcely more than one-sixth of
hole diameter. In the sacculated portion the passage is much
and the walls are thinner in proportion. Small simple and
ed tubular glands, similar to those of the vesiculæ seminales, beset
ucous membrane of this portion of the duct (Henle).

Besides an external areolar investment, and an internal muco brane, the vas deferens is provided with an intermediate thick tunic, of a deep yellowish colour. This coat consists of two plain fibres, an outer of longitudinal and an inner of circular f 599, *d*, *e*). In addition, near the commencement of the tube ternal longitudinal stratum, extremely thin, and constituting than $\frac{1}{5}$th of the muscular coat (fig. 599, *c*).

The lining membrane exhibits on its surface three or four lon ridges, and, besides this, in the sacculated portion of the duct, i by numerous finer rugæ which enclose irregular polyhedral s sembling in this alveolar character the lining membrane of the vesicles. The epithelium is of the columnar kind, and not As in the epididymis there is a deeper layer of small cells bet columnar cells.

Fig. 599.

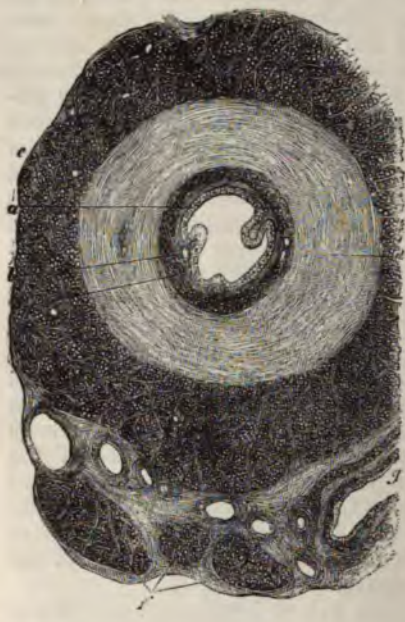


Fig. 599.—Section Across MENCEMENT OF THE VAS (Klein).

a, epithelium; *b*, muc brane; *c*, *d*, *e*, inner, m outer layers of the muscu *f*, bundles of the internal muscles; *g*, section of a bl

Vas aberrans.—This applied by Haller to a lon tube, or diverticulum (fi discovered by him, and variably met with, which from the lower part of of the epididymis, or from mencement of the vas and, becoming tortuous voluted, is rolled up int gated mass which extend for an inch or more an vessels of the spermatic c the tube ends by a clo mity. Its length, whe ravelled, ranges from to twelve or fourteen i its width increases t blind extremity. Som diverticulum is brar occasionally there are such aberrant ducts. Its structure appears to be similar to that deferens. Its origin is probably connected with the Wolffian duct o but the exact mode of its formation and its office are unknown. Lu that occasionally it does not communicate with the canal of the epi appears to be a simple serous cyst.

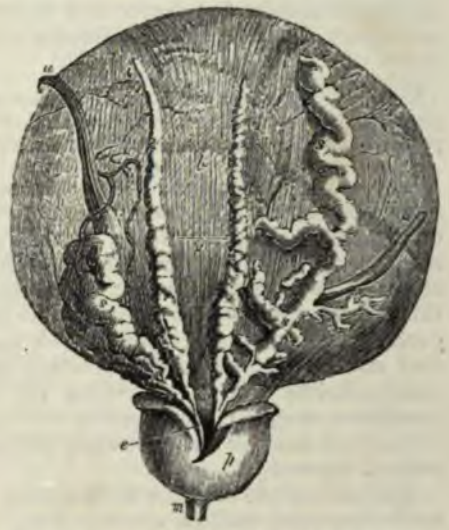
Roth has described other small blind vasa aberrantia lying along th and connected with the rete testis.

Organ of Giraldès.—The small body thus named is situated in the cord immediately above the caput epididymis (see fig. 591, *g*). usually of several small irregular masses containing convoluted tubul columnar ciliated epithelium, and is scarcely to be recognised until t ing connective tissue has been rendered transparent by re-agents. received the name of *parepididymis*. Its tubules appear to be vestig the Wolffian body.

e **seminal vesicles** are two membranous receptacles, situated, one ch side, upon the base of the bladder, between it and the rectum. n distended, they form two long sacculated bodies, somewhat ned on the side next the bladder, to which they are firmly hed, and convex on their inferior surface; they are widened id and narrow in front (fig. 600, *s*). Their length is usually t two inches, and the greatest breadth about half an inch; but vary both in size and shape in different individuals, and also on the ides.

eir posterior obtuse extremities are separated widely from each

Fig. 600.



600.—BASE OF THE MALE DDER WITH THE VESICULÆ INALES, VASA DEFERENTIA, PROSTATE EXPOSED (from er). ½

ne of reflexion of the peri- in the recto-vesical *b*, the part above this hich the peritoneum has moved, exposing the longi- muscular fibres; *i*, left erens ending in *e*, the left tory duct; *s*, left vesicula is joining the same duct; ht vas deferens, and the esicula seminalis, marked and unravelled, are also *p*, under side of the pros- and, cut so as to exhibit the tory ducts; *m*, small part membranous portion of the ; *u*, *u*, the ureters, of the right is turned to the

, but anteriorly they converge so as to approach the two vasa entia, which run forwards to the prostate between them. With asa deferentia thus interposed, they occupy the two diverging sides e triangular portion of the base of the bladder, which lies upon the m, and is bounded behind by the line of reflexion of the recto- l fold of the peritoneum. The seminal vesicles themselves also pon the rectum, but are separated from it by a layer of the recto- l fascia, which attaches them to the base of the bladder.

e sacculated appearance of the seminal vesicles is owing to their iar formation. Each consists of a tube somewhat coiled and tedly doubled on itself, and invested by dense fibrous tissue. unrolled, this tube is found to be from four to six inches long, bout the width of a quill. Its posterior extremity is closed, so that ns a long cul-de-sac; but there are generally, if not always, several r or shorter branches or diverticula connected with it, which also y closed extremities (fig. 600, *s*, *s*). Anteriorly the seminal vesicle es straight and narrowed, and ends opposite the base of the te by uniting on its inner side, at an acute angle, with the narrow nation of the corresponding vas deferens to form a single canal, is the *common seminal or ejaculatory duct*.

In structure, the seminal vesicles resemble very closely the adjoining sacculated portions of the vasa deferentia. Besides an external investment, connected with the recto-vesical fascia, and containing vessels of considerable size, lymphatics, and gangliated nervous cords, they have a muscular coat and a mucous membrane. The muscular layers are thin compared with those of the vas deferens, and consist of three layers, an inner and outer longitudinal, and a middle layer of circular fibres. A considerable amount of plain muscular tissue is found covering the posterior surface and extending transversely between the two vesicles. There are also longitudinal fibres traceable over the vesicles from those of the bladder (Ellis, Henle). The mucous membrane is traversed by very many fine rugæ, which form an alveolar structure resembling that seen in the gall-bladder, but deeper and enclosing much finer meshes. The epithelium of the vesicles is columnar with a deep layer of small polyhedral cells.

The seminal vesicles serve as receptacles or reservoirs for the semen, as is proved by a microscopic examination of their contents; but, besides this, it is probable that they secrete a peculiar fluid which is incorporated with the semen.

The **common seminal** or **ejaculatory ducts**, two in number, are formed on each side by the junction of the narrowed extremities of the corresponding vas deferens and vesicula seminalis, close to the base of the prostate gland. From this point they run forwards and upwards, at the same time approaching each other, and then pass side by side through the prostate between its middle and two lateral lobes. After a course of nearly an inch, during which they become gradually narrower, they end in the floor of the prostatic portion of the urethra by two small slit-like orifices placed on the verumontanum, one on each prominent margin of the opening of the prostatic sinus (fig. 589, *d*). For a short distance the ejaculatory ducts run in the substance of the walls of the vesicle.

The coats of the common seminal duct, as compared with those of the vas deferens and vesicula, are very thin. The muscular coat consists of an outer thin circular and an inner longitudinal layer. The strong areolar tunic almost entirely disappears after the entrance of the ducts between the lobes of the prostate, but muscular fibres may be traced into the prostatic portion. The mucous membrane becomes gradually smoother as it passes into that of the urethra. Its epithelium is like that in the seminal vesicles and vas deferens. According to Henle, the muscular fibres of the duct are separated by blood-vessels as it passes through the prostate and form the trabeculæ of a layer of cavernous tissue.

These ejaculatory ducts convey the fluid contained in the seminal vesicles and vasa deferentia into the urethra. Their canal gradually narrows as they approach their termination, where its diameter is reduced to the $\frac{1}{30}$th of an inch.

Vessels and Nerves of the Testis.—The testicle and its excretory apparatus receive blood-vessels and nerves from sources which are different from those giving the vascular and nervous supply to the coverings of those parts.

The *spermatic artery*, or proper artery of the testicle, is a slender and remarkably long branch, which arises from the abdominal aorta, and passing down the posterior abdominal wall reaches the spermatic cord, and descends along it to the gland. In early fœtal life its course is much shorter, as the testis is then situated [illegible] part of the aorta from which the artery arises. As the vessel

testicle, it gives off small branches to the epididymis, and then ıers which perforate the tunica albuginea at the back of the through the corpus Highmori; some spread out on the internal tunica albuginea, whilst others run between the lobes of the . by the fibrous processes of the mediastinum. The smallest r on the delicate membranous septa between the lobes, before miniferous tubes.

ens receives from one of the vesical arteries a long slender companies the duct, and hence is named the *deferent artery*, or *s deferens*. It ramifies on the coats of the duct, and reaches as where it anastomoses with the spermatic artery (fig. 598, *p*).

veins commence in the testis and epididymis, pass out at their , and unite into larger vessels, which freely communicate with hey ascend along the cord, and form the *pampiniform plexus*. or three veins follow the course of the spermatic artery into the they unite into a single trunk, that of the right side opening va, and that of the left into the left renal vein.

s accompany the spermatic vessels and terminate in the lumbar ls, which encircle the large blood-vessels in front of the verte- as previously stated, they begin from intercommunicating lymph cupy the intervals between the tubuli seminiferi.

e derived from the sympathetic system. The *spermatic plexus* e set of nervous filaments, which descend upon the spermatic aortic plexus. Some additional filaments, which are very minute, ypogastric plexus, and accompany the artery of the vas deferens. seminales receive branches from the *inferior vesical* and *middle rteries* and veins. The nerves belong to the sympathetic system, the hypogastric plexus.

.—The *semen* is a thick whitish fluid, the combined pro- tes and the accessory generative glands.

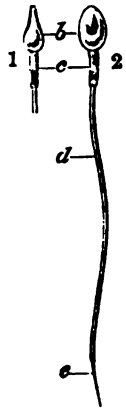
floating in it, besides squamous and columnar epithe- rtain number of small highly refracting globules (*seminal* ner), and the *spermatozoa* or spermatic filaments.

l granules are colourless particles having an average diame- $\frac{1}{100}$th of an inch. They stain deeply with most dyes, and rived from the nuclei of the disentegrated nutritive cells erous tubules.

Fig. 601.

g. 601.—HUMAN SPERMATOZOA (Retzius).

, the tail not represented; 2, viewed on the flat; le-piece; *d*, tail; *e*, end-piece of the tail.



atozoa are peculiar microscopic bodies which e essential element for fecundation of the consists of a flattened oval part or so-called long slender filiform *tail* (fig. 601). At the ıe head with the tail there may frequently be intermediate portion, uniting the two. This the *middle-piece* (Schweigger-Seidel). The $\frac{1}{6000}$th of an inch long and $\frac{1}{10000}$th broad, in its attached than in its free half, so that appears pointed (fig. 601, 1). There is a ion on each surface. The tail is from $\frac{1}{500}$th ı inch in length.

nce shown by Leydig that in the spermatozoon of the salamander ttached to the tail, a delicate undulating membrane. A similar

membrane has been described by H. Gibbes in other vertebrates, in mammals, and he and Jensen also describe a long fine filament as bound membrane along its unattached border. This filament, which is attache head at one end, is considerably longer than the tail itself, so that it as the free edge of the membrane is thrown into undulating coils (see f Retzius, who has still more recently investigated the subject, descri tail as becoming abruptly narrowed near its extremity, which thus distinct terminal portion (fig. 601, *c*); but he fails to detect the later brane and filament in mammals.

Development of the spermatozoa.—The spermatozoa are developed wi seminiferous tubules from the daughter-cells of the spermatoblasts. The its nucleus elongate and the latter passes towards the outer extremity, becomes pointed. The protoplasm of the cell at first forms a clavate pr

Fig. 602.

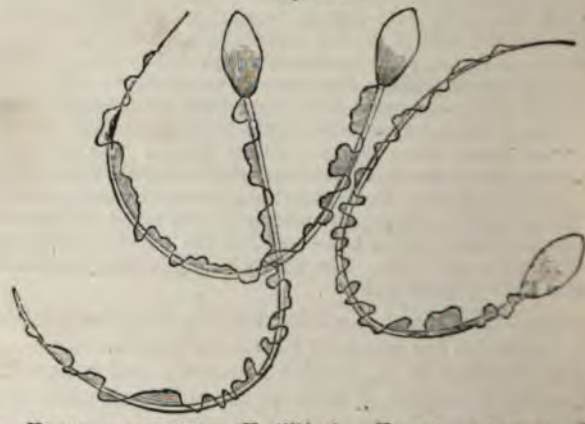


Fig. 602.—Human spermatozoa (H. Gibbes). Highly magnified. Som diagrammatic.

towards the lumen (fig. 594, *a*). Between the nucleus and the more granula plasm is seen an intermediate portion of the cell composed of clear su and partly embracing the pole of the nucleus (fig. 595, *b*). This appears eventually the middle piece of the spermatozoon whilst the nucleus of (or at least the chromatic substance of the nucleus) becomes transform the head, and the granular clavate projection grows out into the tail. stages the head may appear covered by a transparent envelope, probably from the protoplasm of the cell (head-cap of Schweigger-Seidel). The ment of the membrane and filament of Gibbes has not as yet been traced fine filaments may often be seen coiled up within the daughter-cells wh undergoing transformation into spermatozoa, and it is not unlikely tha may be the filaments described by Gibbes, although they have usual regarded as the developing tails of the spermatozoa (Kölliker). The mi is probably a thinned out portion of the protoplasm of the cell.

Motion of the spermatozoa.—The spermatozoa, after their discha removal from the vas deferens or vesiculæ seminales, are found to exhibi lashing movements of the tail with an undulating motion of the attache brane and filament, lasting under favourable conditions for many hour action has the effect of causing them to progress in a somewhat spiral through the fluid in which they float, and by it they are no doubt p upwards in the female generative passages and thus assisted to reach th The conditions under which the action of the spermatozoa is maintain influenced are in almost all respects the same as those influencing the of cilia (see pp. 51 to 54).

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he ducts of the testes, and seminal vesicles. *Klein* in Stricker's Handbook, 1871; *rhans*, in Virch. Arch., LXI, 1874; *Robin et Cadiat*, in J. de l'anat., 1875; *Roth* schr. f. Anat. u. Entw. II. 1876, and in Virch. Arch. LXXXI, 1880.

REPRODUCTIVE ORGANS IN THE FEMALE.

e reproductive organs in the female consist of the ovaries, uterus, Fallopian tubes, which are named the *internal*, and the vagina, s, nymphæ, labia, and other parts included in the vulva, named *ternal* organs of generation.

THE VULVA.

vulva, or **pudendum,** is a general term, which includes all the perceptible externally, viz., the mons Veneris, the labia, the hymen unculæ, the clitoris, and the nymphæ. The urethra also may be ded in connection with these parts.

eguments and Labia.—The integument on the fore part of the symphysis, elevated by a quantity of areolar and adipose tissue, and d with hair, is termed the *mons Veneris*. Two rounded folds of ument (*labia externa v. majora*, fig. 603, 20) extend downwards and rards from below the mons, gradually becoming thinner; they leave iptic interval (*rima*) between them, the outer surface of each being uous with the skin, and covered with scattered hairs, whilst the is lined by the commencement of the genito-urinary mucous mem-. Within the substance of the fold there is found, besides fat, ls, nerves, and glands, a tissue resembling that of the dartos in the m of the male, to which the labia in the main correspond. The majora unite beneath the mons and also in front of the perineum, ro points of union being called the anterior and posterior commis-

The posterior or inferior commissure is about an inch distant the margin of the anus, this interval being the perineum of the . Immediately within the posterior commissure, the labia are con- by a slight transverse fold (*frænulum pudendi*), which is fre- y torn in the first parturition. The space between it and the issure has been called *fossa navicularis*.

toris.—Beneath the anterior commissure, and concealed between bia, is the *clitoris* (fig. 603, 19), a small elongated body correspond- conformation and structure to a diminutive penis, but differing ring no *corpus spongiosum*, nor urethra connected with it below.

It consists of two *corpora cavernosa*, which are attached by crura to the rami of the ischium and pubis, and are united together by their flattened inner surfaces so as to form an incomplete pectiniform septum. The body of the clitoris, which is about an inch and a half long, but is hidden beneath the mucous membrane, is surmounted by a small *glans*, consisting of spongy erectile tissue. The glans is imperforate, highly sensitive, and surrounded superiorly by a membranous fold, analogous

Fig. 603.

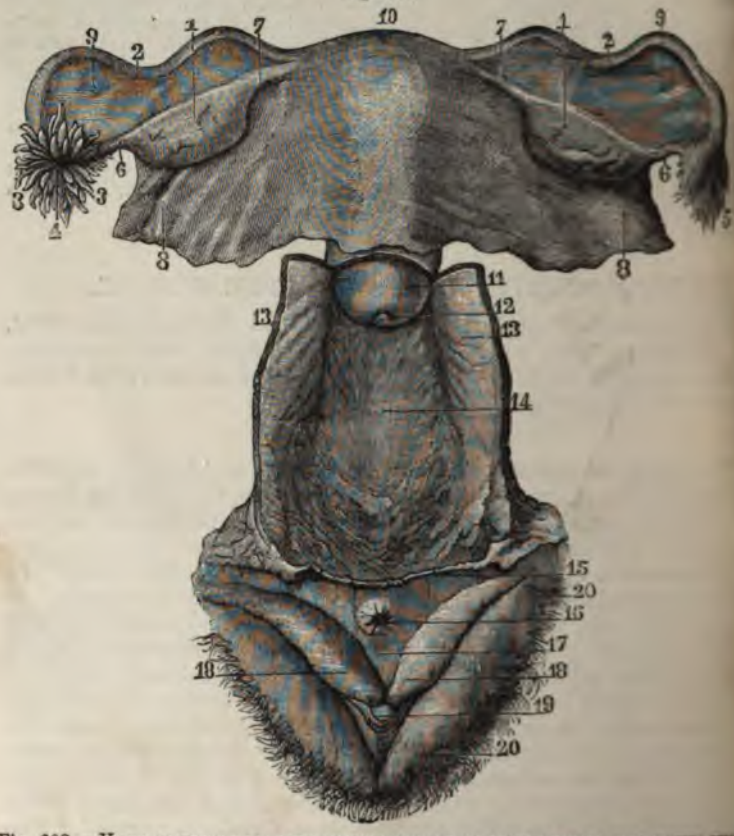


Fig. 603.—VIEW OF THE FEMALE ORGANS OF GENERATION FROM BEHIND, THE VAGINA BEING CUT OPEN AND ITS WALLS TURNED ASIDE (Sappey). ½

1, Ovaries; 2, Fallopian tubes; 3, 4, 5, their fimbriated extremities (4 points to the ostium abdominale); 6, ovarian fimbria; 7, ligament of the ovary; 8, 9, broad ligaments; 10, uterus; 11, its vaginal portion; 12, os uteri; 13, lateral and posterior walls of vagina reflected; 14, its anterior wall; 15, edge of hymen; 16, orifice of urethra; 17, vestibule; 18, nymphæ; 19, clitoris; 20, labia majora.

to the prepuce. There is a small suspensory ligament attached to the upper border, like that of the penis, and in front of this the clitoris is dependent. The two ischio-cavernous muscles, named in the female *erectores clitoridis*, have the same connections as in the male, being inserted into the crura of the corpora cavernosa.

Nymphæ.—From the glans and prepatial covering of the clitoris

r pendulous folds of mucous membrane pass backwards for ıch and a half, one on each side of the entrance to the vagina. the *nymphæ* (*labia interna v. minora*, fig. 603, 18). Their ce is continuous with that of the vagina; the external insensibly the labia majora. They contain vessels between the laminæ tary membrane, but, according to Kobelt, no erectile plexus; ctile structure corresponding to the bulb and spongy body , in two separate right and left halves, as will be presently

Fig. 604.

ATERAL VIEW OF THE ERECTILE S OF THE EXTERNAL ORGANS IN N (from Kobelt). ⅔

-vessels have been injected, and mucous membrane have d; *a*, bulbus vestibuli; *c*, ns named pars intermedia; *e*, is; *f*, body of the clitoris; *h*, *l*, right crus clitoridis; *m*, right gland of Bartholin.

le.—Between the nymphæ ar interval called the *vesti-* 3, 17), in which is situated r orifice of the urethra, or *narius* (16), about an inch litoris and just above the) the vagina. The mem- h surrounds this orifice is minent in most instances y to indicate its situation. tely below the orifice of the urethra is the entrance to the ich, in the virgin, is usually more or less narrowed by the). This is a thin duplicature of the mucous membrane, placed rance to the vagina; its form varies very considerably in ersons, but is most frequently semilunar, the concave margin cted forwards towards the pubis. Sometimes it is circular, forated only by a small round orifice, placed usually a little centre; occasionally it is cribriform, or pierced with several ures; and it may in rare instances completely close the vagina, g "imperforate hymen." On the other hand, it is often) a mere fringe, or it may be entirely absent. After its me small rounded elevations remain, called *carunculæ myrti-*

cous membrane may be traced inwards from the borders of majora, where it is continuous with the skin: it forms a fold scular tissue of the nymphæ, and is then prolonged into the d vagina. It is smooth, reddish in colour, is covered by a elium, and is provided with a considerable number of mucous follicles, and with glands which secrete an unctuous and bstance. The mucous crypts and follicles are especially dis- he inner surface of the nymphæ, and near the orifice of the The sebaceous glands are found beneath the prepuce, and abia majora and outer surface of the nymphæ.

nds of Bartholin (*or of Duverney*) (fig. 604, *n*), correspond-

of venous plexuses, of erectile tissue, corresponding
the male. Besides the corpora cavernosa and glans
referred to, there are two large leech-shaped masses,
(fig. 605, *a*), about an inch long, consisting of a network
in a fibrous membrane, and lying one on each side

Fig. 605.

Fig. 605.—FRONT VIEW OF THE ERECTILE STRUCTURES OF THE
THE FEMALE (from Kobelt). ½

a, bulbus vestibuli; *b*, sphincter vaginæ muscle; *e*, *e*, venous
media; *f*, glans clitoridis; *g*, connecting veins; *h*, dorsal vein of
passing beneath the pubes; *l*, the obturator vein.

little behind the nymphæ. They are rather pointe
extremities, and rounded below: they are suspended,
crura of the clitoris and the rami of the pubes, covered
mucous membrane, and embraced on the outer side by

t-vessels.—The outermost parts of the vulva are supplied by the *super-dic and perineal arteries;* the deeper parts and all the erectile tissues branches from the *internal pudic arteries* as in the male. The veins also in measure correspond; there is a dorsal vein of the clitoris receiving branches e glans and other parts as in the male: the veins of the bulbus vestibuli kwards into the vaginal plexuses, and are connected also with the obtu-ins: above they communicate with the veins of the pars intermedia, those orpora cavernosa and the glans of the clitoris, and also with the vena

The lymphatics accompany the blood-vessels.

es.—Besides *sympathetic branches*, which descend along the arteries, ly for the erectile tissues, there are other nerves proceeding from the and sacral plexuses; those from the former being branches of the *genito-* and those from the latter of the *inferior pudendal* and *internal pudic* which last sends comparatively large branches to the clitoris. They te in the clitoris in peculiar tactile corpuscles (see p. 164).

THE FEMALE URETHRA.

female urethra is short as compared with that of the male sex. out an inch and a half in length; its average diameter is about of an inch, but it is capable of great distension. Its direction is downwards with a slight curvature forwards. It lies embedded anterior wall of the vagina, from which it can only be separated ection.

external orifice, or *meatus urinarius* (fig. 603, 16), opens in the nearly an inch below and behind the clitoris, between the nymphæ, mediately above the entrance to the vagina. From its orifice, is its narrowest part, the canal passes upwards and backwards n the crura of the clitoris and behind the pubis, gradually enlarg-o a funnel-shaped opening as it approaches and joins the bladder. is also a dilatation in the back of the canal, just within the meatus. mucous membrane is whitish, except near the orifice; it is raised ngitudinal folds, which are not entirely obliterated by distension, lly one which is particularly marked on the lower or posterior of the urethra. Near the bladder the membrane is soft and with many tubular mucous glands. Lower down these increase and lie in groups between the longitudinal folds; and immediately and around the orifice, the lips of which are elevated, are several and wider crypts.

lining membrane is covered with a stratified scaly epithelium, but e bladder it becomes transitional. The submucous areolar tissue s numerous elastic fibres. Outside this there is a highly vascular re, in which are many large veins. Between the anterior and or layers of the triangular ligament, the female urethra is ed by the fibres of the compressor urethræ muscle.

vessels and *nerves* of the female urethra are very numerous, and ived from the same sources as those of the vagina.

THE VAGINA.

vagina is a dilatable membranous passage, extending from the o the uterus, the neck of which is embraced by it (fig. 603). It elow and behind on the rectum, supports the bladder and urethra in and is enclosed between the levatores ani muscles at the sides. It htly curved and is directed upwards and backwards: its axis onding below with that of the outlet of the pelvis, and higher up at of the pelvic cavity. Its length is greater along the posterior

than along the anterior wall by about an inch and a half. The end the vagina are somewhat narrower than the middle part: the lower which is continuous with the vulva, is the narrowest part, and widest from before backwards; the middle part is widest from side side, being flattened from before backwards, so that its anterior posterior walls are ordinarily in contact with each other: at its u end it is rounded, and expands to receive the vaginal portion of the of the uterus. The vagina reaches higher up on the cervix uteri be than in front, so that the uterus appears to be inserted into its ant wall.

On the *inner surface* of the vagina, anteriorly and posteriorly slightly elevated ridge extends from the lower end upwards in middle line, forming the *columns* of the vagina, or *columnæ rug* Numerous dentated transverse ridges, called *rugæ*, are also obse particularly in persons who have not borne children, running at angles from the columns. These columns and rugæ are most evi near the entrance of the vagina and on the anterior surface, gradually become less marked, and disappear towards its upper end.

Fig. 606.

Fig. 606.—Sectional view of the viscera of the female pelvis (Allen Th after Houston and from nature). ¼

The pelvic viscera having been distended and hardened with alcohol previ making the section, are somewhat larger than natural and the vagina appears open, w its anterior and posterior walls should be in contact with one another. *p*, promon the sacrum; *s*, symphysis of the pubis; *v*, the upper part of the urinary bl *v'*, the neck; *v''*, *u*, the urethra; *u*, the uterus; *v a*, the vagina; *r*, third part rectum; *r'*, the fold between the middle and upper parts of the rectum; *a*, the an the right labium; *n*, the right nympha; *h*, the hymen; *cl*, the divided clitoris the prepuce.

ıcture and connections.—The walls of the vagina are thickest t, in the vicinity of the urethra, which indeed may be said to be ed in the anterior wall of the vaginal passage; in other situa- ıey are thinner. The vagina is firmly connected by areolar tissue ıeck of the bladder, and only loosely to the rectum and levatores scles; at the upper end, for about a fourth part of its length, its or surface receives a covering from the peritoneum, which ls in the form of a cul-de-sac thus far between the vagina and ;um.

rnally the vagina presents a coat of dense areolar tissue, and ı this its walls are composed of unstriped muscle, which is not ly separable into strata, but is composed chiefly of fibres inter- rcular and externally longitudinal. Round the tube a layer of ectile tissue is found, which is most marked towards the vulva.

s lower end, the vagina is embraced by striated muscular fibres, onstitute the *sphincter vaginæ*, already described.

mucous membrane, besides the columns and rugæ, is provided apillæ, and with numerous mucous glands, especially in its moother portion and round the cervix uteri. It is lined with a d scaly epithelium.

ls and Nerves.—The vagina is largely supplied with vessels and nerves. *ries* are derived from branches of the internal iliac, viz., the *vaginal, in- udic, vesical*, and *uterine*. The veins correspond; but they first surround na with numerous branches, and form at each side a plexus named the *plexus*. The nerves are derived from the *hypogastric plexus* of the sym- , and from the *fourth sacral* and *pudic nerves* of the spinal system; the ıre traceable to the erectile tissue.

THE UTERUS.

uterus or **womb**, (*matrix*, ὑστερον,) is a hollow muscular organ, ry thick walls, situated in the pelvic cavity between the rectum urinary bladder. In the case of pregnancy the uterus receives the retains and supports it during the development of the fœtus, and t at the time of parturition. The Fallopian tubes, extending from per angle of the uterus to their ovarian opening, conduct the om the ovary to the uterine cavity. During gestation, the uterus es a great enlargement in size and capacity, as well as important al changes.

ıe fully developed virgin condition, which is that to which the g description mainly applies, it is a somewhat pear-shaped body, d from before backwards, free above, and connected below with the into which its lower extremity projects (fig. 603). It does not reach he brim of the pelvis. Its upper end is directed upwards and s, the lower downwards and backwards; so that its axis corres- ith that of the inlet of the pelvis, and forms an angle or sudden ith the axis of the vagina, which corresponds more nearly with the outlet of the cavity. The uterus projects upwards into a the peritoneum, by which the body is covered both before and and the neck also behind; but in front the peritoneum does not farther than the body. Its free portion is in contact with the elvic viscera, some convolutions of the small intestine usually pon its upper and posterior surface. Its lower and anterior sur- in contact with the bladder, with the intervention of the peri-

toneal pouch. From its two sides the peritoneum is reflect
form of a duplicature, named the broad ligament.

The average dimensions of the uterus are about three inches
two in breadth at its upper and wider part, and nearly an inch
ness: its weight is from seven to twelve drachms. It i
described as possessing a fundus, body, and neck.

Fig. 607.

Fig. 607.—Sagittal section through the
the upper end of the vagina (Hea

a, anterior; *p*, posterior wall of the va

The *fundus* is the broad bulging
of the body, and projects upwards fro
the points of attachment of the Fallo
(fig. 603, 10). The *body* gradually
as it extends from the fundus to t
its sides are nearly straight; its an
posterior surfaces are both somewha
but the latter more so than the for
the points of union of the sides
rounded superior border are two
angles, with which the Fallopian
connected, the round ligaments being
a little before, and the ovarian
behind and beneath them; these three
all included within the peritoneal d
of the broad ligaments (fig. 603, 8).
of the uterus is of a less rigid consist
the neck and readily becomes bent
upon it either forwards or backwards,
to a great extent the condition of
of the bladder. When the latter is empty the body of t
may be nearly horizontal. The *neck*, or *cervix uteri*, narr
more rounded than the rest of the organ, is nearly an inch i
it is continuous above with the body, and, becoming
smaller towards its lower extremity projects into the upp
the tube of the vagina, which is united all round with the su
the uterus, but extends upwards to a greater distance behin
front. The projecting portion of the uterus is named the *v*
(fig. 603, 11). The axis of the cervix uteri may be in the sam
with that of the vagina, in which case the amount of flexio
the body and neck is greater, or it may be directed forwards
an angle with the direction of the vagina. The lower end of
presents a transverse aperture, by which its cavity opens into
(fig. 603, 12); this is named variously *os uteri*, *os uteri ex*
(from a supposed likeness to the mouth of the tench fish
It is bounded by two thick lips, the posterior of which is
and longer of the two, while the anterior, although projectin
its vaginal attachment, is lower in position, and, when the tu
comes into contact with the posterior wall of the vagina
These borders or lips are generally smooth, but, after partu
frequently become irregular, and are sometimes fissured or cl

Cavity of the uterus.—The walls of the uterus are of gre

and the cavity is thus proportionately much reduced in size. The part within the body is triangular (fig. 608), and flattened from before backwards, so that its anterior and posterior walls touch each other (fig. 607). The base of the triangle is directed upwards, and is convex towards the interior of the uterus. The cavity, narrowing gradually, is prolonged into its two superior angles, at each of which it leads by a minute foramen into the narrow canal of the Fallopian tube. At the junction of the body with the neck, the cavity is slightly constricted,

Fig. 608.

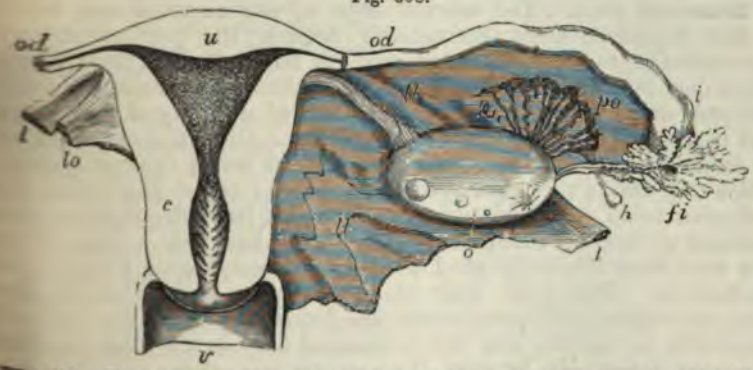


Fig. 608.—Diagrammatic view of the uterus and its appendages, as seen from behind. (A. T.) $\frac{2}{3}$

The uterus and upper part of the vagina have been laid open by removing the posterior wall: on the left side the Fallopian tube, round ligament, and ovarian ligament have been cut short, and the broad ligament removed; *u*, the fundus of the uterus; *c*, the cervix opposite the os internum; the triangular shape of the uterine cavity is shown, and the dilatation of the cervical cavity with the rugæ termed arbor vitæ; *v*, upper part of the vagina; *od*, Fallopian tube or oviduct; *l*, round ligament; *lo*, ligament of the ovary; *o*, ovary (here represented with its long axis horizontal although in the natural position within the body it is oblique or nearly vertical); *i*, wide outer part of the right Fallopian tube; *fi*, its fimbriated extremity; *po*, parovarium; *h*, one of the hydatids frequently found connected with the broad ligament.

and thus forms what is sometimes named the *internal orifice* (*os uteri internum*, *isthmus vel ostium uteri*); this opening is often smaller than the os externum, and is of a circular form. That portion of the cavity which is within the neck is tubular and slightly flattened before and behind: it is somewhat dilated in the middle, and opens inferiorly into the vagina by the os tincæ. Its inner surface is marked by two longitudinal ridges or columns, which run, one on the anterior, the other on the posterior wall, and from both of which rugæ are directed obliquely upwards on each side, so as to present an appearance which has been named *arbor vitæ uterinus*, or *palmæ plicatæ* (fig. 608): this structure is most strongly marked anteriorly.

Structure.—The walls of the uterus consist of an outer serous covering, an inner mucous membrane, and thick intermediate muscular substance. The serous covering or *peritoneal* layer has been already referred to.

The thick middle part of the wall of the uterus is of firm consistence: being mainly composed of plain muscular fibres of small size, $\frac{1}{110}$ inch in length, in the unimpregnated uterus, but greatly enlarged (to $\frac{1}{40}$th inch) in the gravid state. These fibres interlace closely with each other,

but are disposed in bundles and layers, and are intermixed with areolar tissue, a large number of blood-vessels and lymphatics, and some nerves. The areolar tissue is more abundant near the outer surface. The arrangement of the muscular fibres is best studied in the uterus at the full period of gestation, in which the bundles become augmented in size. They may be referred to three sets of which the two more external may be regarded as corresponding with the muscular coat of other hollow viscera, whereas the internal is an immensely hypertrophied *muscularis mucosæ*, and will accordingly be described with the mucous membrane.

Muscular coat.—The *external layer* of the muscular coat forms a thin superficial sheet immediately beneath the peritoneum, and incomplete strata situated more deeply. A large share of these fibres, beginning as longitudinal bands at the cervix, arch transversely and obliquely over the fundus and adjoining part of the body of the organ, and pass on each side into the broad ligament. Of these some converge at either side towards the commencement of the round ligaments, along which they are in part prolonged to the groin; others pass off to the Fallopian tubes, and strong transverse bands from the anterior and posterior surfaces are extended into the ovarian ligaments. Other fibres run back from the cervix uteri beneath the recto-uterine folds of the peritoneum. The *inner layer* of the muscular coat, which is also thin, is composed of fibres which are found chiefly on the back of the uterus, and stretch over the fundus and towards the sides, running somewhat irregularly between the ramifications of the blood-vessels. The muscular coat proper seldom exceeds ¼ inch in thickness altogether, but it is not easy to assign its limits exactly, for there is little or no submucous areolar tissue forming a distinct coat as in most of the hollow viscera. It is chiefly the place of ramification of the blood-vessels before they pass into the mucous membrane that determines the boundary between the muscular layer of the mucous membrane and the muscular coat proper (J. Williams).

Fig. 609.

Fig. 609.—Section of the uterine mucous membrane parallel to the surface (Heule). $\frac{150}{1}$

1, 2, 3, glands (the epithelium has fallen out from 2); 4, a blood vessel.

Mucous membrane.—The mucous membrane of the uterus is characterised by the enormous hypertrophy of the muscular layer proper to it—the muscularis mucosæ; indeed it is this which forms the greater part of the thickness of the uterine wall. The presence of this mass of plain muscular tissue in it confers a distinct character on the outer part of the membrane, so that in sections it is distinctly differentiated from the inner part or corium.

Muscularis mucosæ.—This consists of bands of fibres which are disposed with comparative regularity in its upper part, being arranged there in numerous concentric rings round the openings of the two Fallopian

Fig. 610.

Fig. 610.—Section of the mucous membrane of the uterus from near the fundus (adapted by J. C. Ewart from a figure by J. Williams).

a, epithelium of inner surface; *b*,*b*, uterine glands; *c*, interglandular connective tissue; *d*, part of the muscularis mucosæ with the ends of the glands, some of which, *b'*, are entirely filled by epithelium cells. This specimen was prepared from the uterus of a young woman who was accidentally killed three or four days before the expected appearance of the menstrual flow.

tubes, the widest circles of the two series meeting from opposite sides in the middle of the uterus. In the lower part of the body, and in the cervix the internal fibres run more transversely. They form the so-called sphincters of the os internum and os externum. At the neck, however, there are also longitudinal fibres within the transverse.

Corium.—As regards its inner part or corium the mucous membrane lining the cavity of the body differs greatly from that of the cervix, a distinct line of demarcation separating the two parts at the isthmus.

The *mucous membrane of the body* of the uterus is smooth, except during the menstrual period, and in the unimpregnated state is entirely devoid of ridges; it is of a peculiar soft spongy consistence, and of a dull, reddish colour.

Under the microscope it appears composed in great measure of small rounded, spindle-shaped, or irregular cells imbedded in a homogeneous ground-substance and with but few connective tissue fibres (figs. 609, 610). According to Leopold, however, there are numerous fibres, and they form a spongework with lymphatic spaces in the meshes. The inner surface is everywhere covered by columnar ciliated epithelium, and is beset, but somewhat sparingly, by the orifices of the uterine glands (fig. 610, *b*). These which were discovered by Sharpey,

are simple tubes bounded by a basement membrane and lined with ciliated columnar cells like those covering the inner surface. They pass usually obliquely and often with an irregular or convoluted course into the deeper part of the mucous membrane, and there terminate by blind, sometimes forked extremities, which are situated amongst the bundles of the muscularis mucosæ. Towards their extremities the uterine glands are entirely filled by cells (fig. 610, *b*), but in the greater part of their extent they present a distinct lumen.

The *membrane of the cervix* is much firmer and more fibrous than that of the body. Between the rugæ of the *arbor vitæ* there are numerous saccular and tubular glands. In the lower part of the cervix the mucous membrane is beset with vascular papillæ, and the epithelium is stratified, but in the upper half or more the epithelium is columnar and ciliated like that of the body. The glands, which are short, with a large lumen, are everywhere lined with columnar ciliated epithelium, even where the epithelium of the surface is stratified. Besides the follicular glands there are also the so-called *ovula Nobothi*, clear or yellowish vesicles of variable size, but visible to the naked eye, embedded in the membrane. These may arise from closed and distended follicles ; but their exact nature is still doubtful.

During pregnancy the mucous glands of the cervix secrete a considerable quantity of tenacious mucus, which effectually closes the passage downwards from the uterine cavity.

The surface of the os uteri is covered, like the vaginal portion, with stratified epithelium which conceals the vascular papillæ. It is destitute of glands.

LIGAMENTS OF THE UTERUS.—Where the peritoneum is reflected from the uterus to the bladder in front, and to the rectum behind, it forms, in each position, two semilunar folds, named respectively, the *vesico-uterine*, and the *recto-uterine folds*, or sometimes the *anterior* and the *posterior ligaments* of the uterus.

The *broad ligaments* (figs. 603, 608), are formed on each side by a fold or double layer of the peritoneum, which is directed laterally outwards from the anterior and posterior surfaces of the uterus, to be connected with the sides of the pelvic cavity. Between the two layers of the serous membrane are placed, firstly, the Fallopian tube, which runs along the upper margin of the broad ligament ; secondly, the round ligament, which is a little farther down and lies anteriorly ; thirdly, on the posterior surface, the ovary and its ligament, which lie in a special extension of the ligamentum latum ; and, lastly, throughout the greater part of the broad ligament, blood-vessels, lymphatics, and nerves, with fibres spreading from the superficial muscular layer of the uterus. The *ligament of the ovary* is merely a dense fibro-areolar cord, containing some uterine muscular fibres, and measuring about an inch and a half in length, which extends from the inner (or, in the natural position, lower) end of the ovary to the upper angle of the uterus, which it joins immediately behind and below the point of attachment of the Fallopian tube ; it causes an elevation of the posterior layer of the serous membrane, and, together with the ovary itself, forms the lower limit of a triangular portion of the broad ligament, which has been named the *ala vespertilionis* or bat's wing.

The *round ligaments* are two flat, cord-like bundles of fibres, about four or five inches in length, attached to the upper angles of the uterus, one on either side, immediately in front of the Fallopian tube. From

oint each ligament proceeds upwards, outwards, and forwards, to he internal inguinal ring, and after having passed, like the sper- cord in the male, through the inguinal canal, reaches the fore part pubic symphisis, where its fibres expand and become united with bstance of the mons Veneris. Besides areolar tissue and vessels, und ligaments contain, chiefly in their inner third, plain muscular which are prolonged into them from the outer muscular layer of erine wall. Each ligament also receives a covering from the peri- n, which, in the young subject, projects under the form of a tubular s for some distance into the inguinal canal; this, which resembles ocessus vaginalis originally existing in the same situation in the is named the canal of Nuck; it is generally obliterated in the but is sometimes found even in advanced life.

sels.—The *arteries of the uterus* are four in number, viz., the right and erian (which correspond to the spermatic of the male) and the *uterine*. rigin, as well as the mode in which they reach the uterus and ovaries, has lescribed in the first volume. They are remarkable for their frequent noses, and also for their singularly tortuous course. After passing a short e into the thickness of the uterine wall they divide into branches, which ate the muscular tissue of the mucous membrane, supplying it with aries, and then pass towards the inner portion of the membrane and open network of large capillaries which pervades the tissue in that situation. e especially developed near the surface and around the glands. In the cer- owever, and especially in the vaginal portion, the arteries, which in this ion possess walls of considerable thickness, after entering the mucous ane, divide into a number of small branches which pass directly towards rface and open into the capillary network there present, from which loops into the papillæ. The *veins* correspond with the arteries; they are very and form plexuses of sinus-like vessels, with thin walls in immediate con- with the uterine tissue. The *lymphatics* commence according to Leopold as like spaces in the mucous membrane, but there are also well-marked lym- vessels extending as a plexus through the whole thickness of the mem- (Hoggan). These open into plexuses of vessels in the muscularis mucosæ uscular coat proper; and these again are in communication with valved beneath and in the serous covering.

ves.—The nerves are derived from the *inferior hypogastric plexuses*, the *stic plexuses*, and the *third* and *fourth sacral nerves*. They consist of both lated and non-medullated fibres, and in animals small ganglia have been ed in the submucous tissue, connected with the non-medullated fibres.

lodic structural changes in the Uterus.—The changes which accompany ruation and gestation may be shortly indicated here.

ach successive recurrence of *menstruation* a complete removal of the super- part of the mucous membrane takes place by a process of softening and ular disintegration which commences, along with the menstrual discharge, o the cervix, or at the os internum, and advances progressively towards undus during the remaining days of the flow of blood (J. Williams). ue to this change, there is a greatly increased general vascularity of the and the mucous membrane becomes very much thicker. The process of dis- ation reaches as far as the inner fibres of the muscularis mucosæ; and the rhage is the direct result of the destruction and open condition of the vessels.

process of restoration of the uterine membrane, which begins even before sation of the menstrual flow, proceeds in the same order, from the lower pwards to the fundus, and consists in a very rapid proliferation of the cells uclei which occupy the interstices of the inner muscular fibres, and among , are embedded the deepest parts of the utricular glands. The lining mem- of the cervix does not participate in the changes referred to.

In *gestation* more extensive alterations ensue. The weight of the increases from about one ounce to a pound and a half or even three pounds colour becomes darker, its tissue less dense and its muscular bundles more ea A very great increase takes place in the muscular tissue, this increase mainly the result of the enlargement of the already existing elements, the becoming enlarged to the extent of from seven to eleven times in length from two to five times in breadth (Kölliker). A formation of new cells is said to occur mainly in the innermost layers, and to continue until the month of pregnancy, when it ceases. The round ligaments become enlarge their muscular structure more marked; the broad ligaments are encroached by the intrusion of the growing uterus between their layers. The mucous brane and the glands of the body of the uterus undergo an enlargement similar to that which precedes menstruation, and they subsequently becom

Fig. 611.

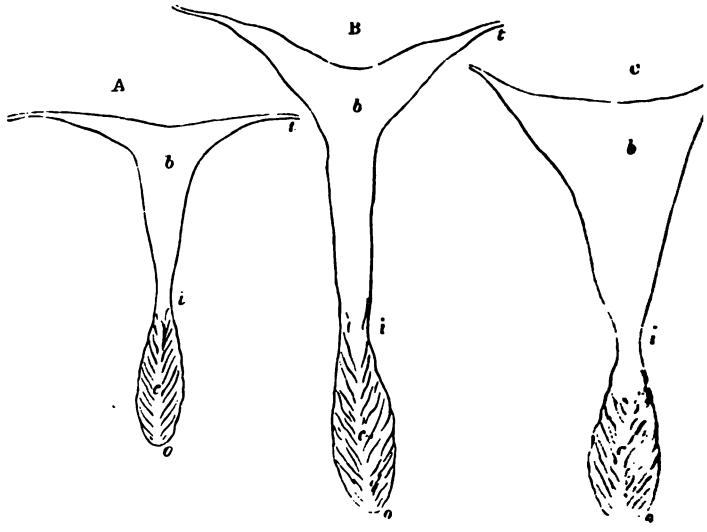


Fig. 611.—Outlines of moulds of the uterine cavity in different sta P. Guyon). Natural size.

A, in a virgin of 17 years of age; B, in a woman of 42 years who had children; C, in a woman of 35 years who had borne children; *b*, cavity of the that of the cervix; *i*, the isthmus or os internum; *o*, os externum; *t*, passa upper angle into the Fallopian tube.

seat of peculiar changes, to be more particularly stated under Devel whilst the membrane of the cervix loses its columns and rugæ. The bloo and lymphatics are greatly enlarged, and it is observed that the arteries exceedingly tortuous as they ramify upon the organ. The nerves also considerable increase in size.

After parturition, the uterus gradually but rapidly diminishes till it re size and structure of the unimpregnated condition. During this ch enlarged muscular fibres undergo fatty degeneration and are said to subsequently absorbed, while a new set of fibre-cells is developed. A first pregnancy, however, the organ never regains its original virgin c In those who have had children its weight usually remains from two ounces; its cavity is larger (fig. 611, C); the os externum is wider and more and its margins often puckered or fissured; the arteries continue much t tuous, and its muscular fibres and layers remain more defined than in th

Changes from Age.—In the infant, the neck of the uterus is larger than the body; the fundus is not distinguished either by breadth or convexity of outline, and the cavity is remarkably narrow, and tapers out from the middle on both sides so as to present an approach to the two-horned form prevalent in animals. These parts afterwards enlarge gradually, until, at puberty, the pyriform figure of the womb is fully established (fig. 611, A.) The arbor vitæ is very distinct, and indeed at first reaches upward to the highest part of the cavity. The shape of the cavity of the body varies also in after life; but it remains comparatively narrow up to the age of puberty, and retains the same form to a great degree in all women who have borne no children (B). It is chiefly, therefore, in those who have been pregnant that its form is widely triangular (C).

From the gradual effects of more advanced age alone, independent of impregnation, the uterus shrinks, and becomes paler in colour, and harder in texture; its triangular form is lost; the body and neck become less distinguishable from each other; the orifices also become less characteristic.

Malformations.—The uterus is subject to numerous congenital malformations, especially in connection with abnormal conditions of the other genital organs. These will be referred to under Development. As a malformation affecting the uterus itself may here be mentioned the more or less double or divided state of the cavity, produced by the prolongation of a septum downwards into it from the fundus. This is sometimes only partial and confined to the upper part of the cavity; while in other instances it involves the whole cavity or also that of the cervix; and even extends through a part or the whole of the vagina.

THE FALLOPIAN TUBES.

These tubes may be considered as ducts of the ovaries (oviducts) and serve to convey the ovum from thence into the uterus. They are inclosed, as already stated, in the free margin of the broad ligaments, and are between three and four inches in length. Their inner or attached extremities, which proceed from the upper angles of the uterus, are narrow and cord-like (fig. 608, *od*): but they soon begin to enlarge, and proceeding outwards, one on each side, pursue an undulatory course, and at length, having attained the width of about a sixth of an inch or more (*i*), they bend backwards, inwards, and downwards towards the ovary. About an inch beyond this they terminate in an expanded extremity, the margin of which is divided deeply into a number of irregular processes named *fimbriæ* (*fi*); one of these, somewhat longer than the rest, is attached to the upper end of the corresponding ovary (fig. 603). The wide and fringed end of the Fallopian tube, or *trumpet*, as the term "tuba" literally signifies, is turned towards the ovary, and is named the *fimbriated extremity* (morsus diaboli). In the midst of these fimbriæ, which are arranged in a radiated manner, the tube itself opens by a round constricted orifice (fig. 603, 4), *ostium abdominale*, placed at the bottom of a sort of fissure leading from that fringe which is attached to the ovary. It is by this orifice that an ovum is received at the time of its liberation from the ovary, and is thence conveyed along the tube, which narrows very much towards its uterine extremity, and opens into the womb by a minute orifice, admitting only a fine bristle, and named *ostium uterinum*. The canal becomes gradually larger towards its abdominal orifice, where it is again somewhat contracted: hence the term *isthmus*, given by Henle to the uterine half, and *ampulla* to the outer half of the Fallopian tube. A second smaller fimbriated opening not unfrequently occurs at a short distance from the main one.

Beneath the external or peritoneal coat the walls of the tube contain, besides areolar tissue, plain muscular fibres, arranged in an external

that of the uterus, columnar and ciliated; the inner s
fimbriæ is also provided with cilia, on their outer or ser
passes into the pavement epithelium of the peritoneal m
does not appear that there are glands, as was at one tim
the mucous membrane lining the Fallopian tubes.

Recent Literature.—On the structure of the uterus:—*Lindgren* Ark., 1867; *Helié*, Rech. sur la dispos. des fibres musc. &c., 1869; *C* Stricker's Handbook, 1871; *Lott*, Anat. u. Phys. d. cervix uteri, Erlangen in Landzert's Beitr., St. Petersb., 1872 (musculature); *Snow Beck*, XIII.; *Schiff*, in Wien. med. Jahrb., 1872 (round ligament); *J. Williams* 1873—1875, and Proc. R. S., 1874; *Kundrat u. G. J. Engelmann*, in W 1873; *Hagemann*, in Arch. f. Gynäk. V.; *Leopold*, in Arch. f. Gy (lymphatics), and XI. and XII. (str. of muc. membr.); *Elischer*, in Arc (muscular tissue and nerves); *G. Hoffmann*, in Arch. f. Anat., 187 *Wyder*, in Arch. f. Gynäk. XIII., 1878; *Ellenberger*, in Arch. f. Thie *Miersejewski*, in Journ. de l'anat., 1879 (lymphatics); *Bandl*, in Ar (cervix uteri); *Klotz*, Gynäk. Studien, &c., Wien, 1879 (cervix uteri); tralbl. f. Gyn., 1880 (nerves); *Veit*, in Zeitschr. f. Geburtsh. V., 188 *G.* and *F. E. Hoggan*, in Journ. of Anat., 1881 (lymphatics).

On the position and form of the uterus:—*Guyon*, Cavité de l'Utérus la Physiol. II.; *J. Williams*, The Physiological Changes in the Positio 1873; *Braxton Hicks*, in Brit. Med. Journ. 1876; *B. S. Schultze*, in A 1876, and Centralbl. f. Gyn. 1878; *Frankenhauser*, in Correspond.-bl arzte VI. 1876; *Fürst*, in Tagebl. d. 49. Versamml. Deutsch. Arzte, 18 in Z. f. Geburtshülfe I. 1876; *Schröder*, in A. f. Gyn. IX. 1876; *H* Anat. d. Steril., Braunsw., 1878; *Hach*, Diss., Dorpat, 1877; *Lang* Gyn. XIII. 1878; *His*, Ue. Prep. z. Situs Viscerum in A. f. Anat. 18 in Amer. Journ. of Obstet., 1878 (contains very complete literature in Edinb. Med. Journ. XXIV. 1879; *Küstner*, in A. f. Gyn. XV.; Pract., 1879; *Kocks*, Lage d. Uterus, Bonn, 1880.

On the Fallopian tubes:—*Hennig*, in A. d. Heilk. XVIII. 1877, a XIII. 1879.

THE OVARIES.

The **ovaries** are two somewhat flattened oval bodies, wh one on each side of the pelvis, enveloped in the posterio broad ligament of the uterus. The weight of each is fr hundred grains, and they usually measure about one inch length, three quarters of an inch in width, and nearly ha

ccording to Kölliker, the ovary is most frequently placed obliquely, long axis parallel to the external iliac vessels, its surfaces directed d outwards, and its free border upwards and forwards. His, on the

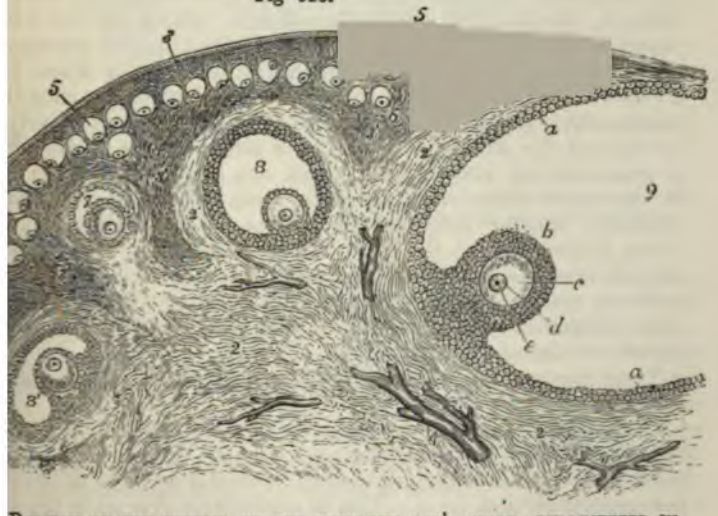
Fig. 612.

—SECTION OF THE OF THE CAT (from). 4/1

overing and free the ovary ; 1', order ; 2, the ian stroma, pre- rous and vascu- ; 3, peripheral blood-vessels ; 5, llicles in their es lying near the , 7, 8, more follicles which d more deeply a ; 9, an almost icle containing in its deepest a follicle from vum has accidentally escaped ; 10, corpus luteum.

, states that the ovary is naturally vertical, with its free border turned . It frequently happens that the uterus is inclined somewhat to one hen the lower end of the opposite ovary is drawn inwards to a cer- degree, so that the organ assumes a more transverse position

Fig 613.



PORTION OF THE SECTION OF THE PREPARED CAT'S OVARY, REPRESENTED IN THE PRECEDING FIGURE, MORE HIGHLY MAGNIFIED (from Schrön).

lium and outer covering of the ovary ; 2, fibrous stroma ; 3, 3', less fibrous, ficial stroma ; 4, blood-vessels; 5, small Graafian follicles near the surface ; wo more deeply placed ; 7, one farther developed, enclosed by a prolongation us stroma ; 8, a follicle farther advanced ; 8', another which is irregularly ; 9, part of the largest follicle ; *a*, tunica granulosa ; *b*, discus proligerus ; , germinal vesicle ; *e*, *germinal* spot.

Structure of the ovary.—The ovary consists of stroma, consisting of connective tissue with blood-vessels, nerves, and plain muscular fibres, and it has an outer epithelial covering, in which are embedded Graafian follicles containing ova.

Epithelium and stroma.—The external surface of the ovary is of a whitish colour, and in early life is comparatively smooth and even; but in later life it becomes more uneven and is marked by pits and scars. It is covered by an epithelium which differs from that of the peritoneum in being composed of pyriform or columnar cells: and the surface has a dull appearance as compared with the shining smoothness of the serous membrane. A distinct line of demarcation exists around the attachment of the ovary, where the two kinds of epithelium pass into each other. This ovarian epithelium is the remains of the *germ-epithelium* from which the ova, and probably the other cells within the Graafian follicles have been developed in the embryo. Here and there are occasionally to be seen amongst the ordinary epithelium-cells, others which are much enlarged and of a spherical form. These are primitive ova, similar to those from which the permanent ova are formed in the fœtus and young subject, and it is probable that even in the adult the formation of ova from cells of the germ-epithelium may proceed to some extent.

Within the epithelium a firm layer of fibrous tissue encloses all the deeper parts. This has been compared to the dense fibrous covering of the testicle, and thence named tunica albuginea ovarii, but without sufficient reason, for it is not a distinct tunic, and is in fact no more than a condensed part of the ovarian stroma.

The *stroma* is chiefly composed of a fine connective tissue, in which the cells, many of which are spindle-shaped, are remarkably abundant and distinct. Besides the spindle-shaped cells, others are met with which closely resemble the interstitial cells of the intertubular substance of the testis. Like these, they have a polyhedral or irregular shape and often a yellowish colour, and they are chiefly found accompanying the blood-vessels, although in older ovaries they may be very extensively diffused throughout the stroma. The stroma also contains elastic tissue, and is permeated by blood-vessels, which are large towards the hilus and in the centre of the ovary where the tissue is more fibrous, and become gradually smaller towards the surface. Along these blood-vessels in the deeper part of the ovary bands of muscular fibres run, having entered from the broad ligament; but it is uncertain whether they extend into the more superficial parts of the ovarian stroma. According to some authorities the spindle-shaped cells which characterize the ovarian stroma are also of muscular nature.

There is a general radial disposition of the bands of stroma from the hilus towards the surface.

Graafian Follicles.—Immediately under the superficial covering of the ovary there is a layer of stroma somewhat different from the deeper parts, and which is so uniformly spread over the organ as to have received the name of cortical layer. This is particularly obvious in the ovaries of some animals (fig. 612, 5) and of young children, in whom this layer is comparatively thick, and to the naked eye its appearance is granular from the accumulation in it of an immense number of closely set small vesicles, constituting the early condition of the ovarian or Graafian follicles with their contained ova. Embedded more deeply in the substance of the ovary are seen other larger and less numerous follicles

ng size, the largest being also the most deeply seated. The very
nowever, which are approaching maturity, eventually reach the
igain, owing to their being gradually more and more distended
id, and may there be seen projecting somewhat, in the form of
sicles, from one-twentieth to one-sixth of an inch in diameter.
hese are punctured or ruptured a drop of clear fluid (*liquor*
escapes, carrying with it the minute ovum surrounded by
nulation of the epithelium-cells of the follicle, known as the
roligerus. Rupture of a Graafian vesicle, or it may be of
ian one, occurs in healthy females at or before every

Fig. 614.

4.—Section of the ovary of a newly-born child. Highly magnified (Waldeyer).

an or germinal epithelium ; *b*, formation of an ovarian tube ; *c*, *c*, primordial
n the germ-epithelium ; *d*, *d*, longer tube becoming constricted so as to form
lls ; *e*, *e*, larger nests ; *f*, distinctly formed follicle with ovum and epithelium ;
-vessels.

e menstrual period. After the discharge of its contents, the
id collapsed Graafian follicle becomes filled with a peculiarly
yellow tissue and constitutes a body termed *corpus luteum*.
pregnancy occur, this body undergoes a considerable develop-
nich is maintained during the greater part of the time of utero-
. But in the unimpregnated female the corpus luteum begins
rade within ten or twelve days after its commencement, and after-
rinks and ultimately disappears. Other follicles, especially before
the child-bearing period, may after advancing to a certain stage
opment undergo a retrograde metamorphosis, their contents be-
broken up and liquefied and their walls collapsed and converted
n-vascular homogeneous membrane. Follicles in this condition
t all unfrequent in the deeper parts of the ovary (fig. 615, *k*).

ition to Graafian follicles in various stages of development and
ion, there may also occasionally be seen in sections of the adult ovary
antly in that of the young subject, cords or tubes composed of rounded

or polyhedral cells, sometimes with developing ova imbedded amongst the
cells. These cords may be in continuity with the germinal epithelium or
may be altogether cut off from it. Others occur which are partially
into rounded nests of cells by growth of the stroma across the cords, and
nests or groups are found entirely separated, and with or without a
ovum in the centre. It is from these nests of cells that the Graafian
become developed, but the mode in which this occurs and also the
which the primitive ova undergo in becoming converted into the
ova, will be described in the Chapter on Development.

Structure of the Graafian follicles.—The smallest
follicles have no proper wall. They consist merely of a single
imbricated flattened cells, immediately investing the contained
In section, the cells look spindle-shaped in the human subject,
very unlike the cells of the ovarian stroma, so that they were
Foulis to be derived from those cells; but the observations of
and others upon the lower animals tend to confirm the view
first stated by Waldeyer that, like the ova themselves, these
thelium-cells of the follicles are originally derived from the
epithelium. These smallest follicles are very numerous, especially in
young subject; indeed, it has been computed that in the ovaries of a
female child at birth there cannot be fewer than 70,000 of them. If
is the case, a large proportion must degenerate and disappear
coming to maturity. Their size is about $\frac{1}{100}$th of an inch.

In follicles which are a little larger, and situated somewhat more
in the stroma, the epithelium-cells, although still in a single
no longer flattened but cubical; a *membrana propria* or
membrane can be detected, and the layer of stroma next to the
beginning to be somewhat differentiated from the rest so as to
special fibrous wall to the follicle. In others again a second layer of
is beginning to be formed or may be found entirely formed within
first, and of the two layers thus produced, one immediately
ovum, and the other lines the wall of the follicle. The former is
beginning of the *discus proligerus*, and the latter of the
granulosa. The cells of both layers soon become columnar.

In most animals the second or inner layer of cells appears to be formed by division of the cells of the first formed layer, but in the rabbit the appearances which are observed appear to justify the assumption that the inner layer is formed at the expense of the peripheral part of the ovum itself (E.A.S.).

In follicles which are still larger, fluid is seen to be
between the two layers of cells, and thus to distend the follicle.
collection of fluid is absent at one part, generally that which is
away from the surface of the ovary, so that here the cells which
the ovum are in continuity with those which line the follicle, and
ovum is thus in a manner attached at this place to the wall of the
(see fig. 613). In the largest follicles the chief difference in the
of the follicle consists in the far greater accumulation of the liquor
and in the multiplication of the epithelium-cells—both those which
the follicle (membrana granulosa) and those which invest the ovum
proligerus)—so that each of these parts consists, in large follicles,
several layers of cells, mostly rounded or irregular, but columnar
wall of the follicle and the exterior of the ovum respectively.

The larger follicles have a very distinct wall, which is
and derived from the stroma of the ovary, and is separable into

s, an inner containing the ramifications of the capillary blood-vessels, ch are abundantly distributed to the larger follicles, but nowhere trate amongst the epithelium cells; and an outer part more fibrous, in

Fig. 615.

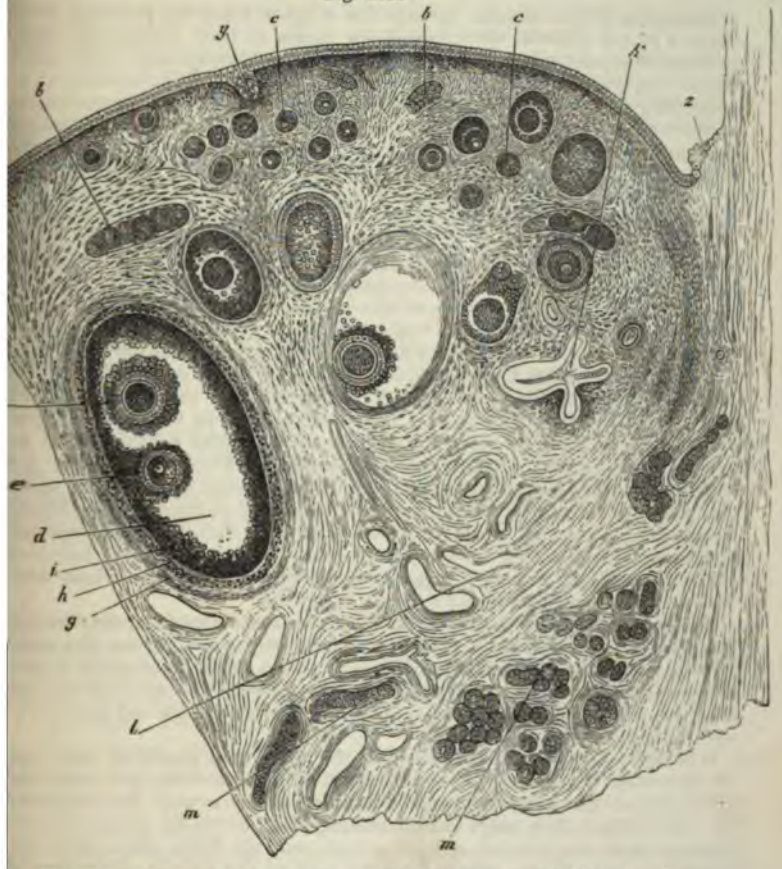


Fig. 615.—Section of the ovary of an adult bitch (Waldeyer). ½

germ-epithelium; *b*, egg-tubes; *c*, *c*, small follicles; *d*, more advanced follicle; cus proligerus and ovum; *f*, second ovum in the same follicle (this occurs but y); *g*, outer tunic of the follicle; *h*, inner tunic; *i*, membrana granulosa; *k*, collapsed graded follicle; *l*, blood-vessels; *m*, *m*, longitudinal and transverse sections of tubes e parovarium; *y*, involuted portion of the germ-epithelium of the surface; *z*, place of ransition from peritoneal to germinal or ovarian epithelium.

ch the larger branches of the blood-vessels of the follicle run. In both rs of the follicular wall, the cells are similar to those of the general ma, interstitial cells occurring abundantly; but it is uncertain whether e are any cells present of the nature of muscular fibres. The smaller l-vessels running round the follicle from below, and minutely sub-led on its inner surface, converge towards a point near the middle ne most projecting part, called the *stigma*. This marks the spot e the rupture of the vesicle ultimately occurs, when fully matured.

Each Graafian follicle usually contains only a single ovum: but occasionally, though seldom, two ova, and very rarely three, have been observed in the same follicle. The structure of the ovum will be described in the Chapter on Development.

Structure of the corpora lutea.—The corpora lutea are produced after the rupture of the Graafian follicles and the escape of their contents by what may perhaps be most correctly described as a process of hypertrophy which the walls of the empty follicles undergo, without the follicle itself submitting to a corresponding amount of enlargement. The result is that the hypertrophied follicular wall is thrown into plaits or folds which as they increase in extent occupy more and more of the cavity of the empty follicle, until this has become entirely filled. The hypertrophy appears to be chiefly the result of the proliferation of the polyhedral interstitial stroma-cells, which as already stated occur in the wall of the follicle in abundance, and there is in addition a considerable development of blood-vessels, which run, accompanied by fibrous tissue, into the folds into which the wall of the follicle is thrown, giving off capillaries which ramify abundantly in the folded wall. Meanwhile the irregular cleft-like space which now alone represents the cavity of the follicle, as well as the opening resulting from the rupture of the follicle and by which its cavity communicated with the surface, have become occupied by a sort of cicatricial fibrous tissue, which constitutes a sort of hilus for the follicle. To this central fibrous band the strands of fibrous tissue which accompany the blood-vessels in the folds of the hypertrophied follicular wall converge. And at the same time the plaited disposition of the wall becomes in great measure obscured, so that a section of a corpus luteum, when advanced in development, exhibits a fibrous framework having a somewhat radial disposition, with the intervals between the radiating trabeculæ occupied by a tissue which is almost wholly composed of the yellowish interstitial stroma-cells. Amongst these cells are numerous cleft-like lymphatic spaces, and except for the fact that capillary blood-vessels also ramify between the yellowish cells, the structural appearances are not unlike those which are met with in the cortical part of the suprarenal capsule.

The corpus luteum is at first marked off from the surrounding ovarian stroma, but after a time its limits are less well defined, at the same time that many of its cells wander into the neighbouring parts of the stroma, into which it may be said gradually to merge and in this way to disappear. The result is that, as age advances, the stroma of the ovaries becomes gradually more and more permeated with interstitial cells.

It is asserted by some that the cells of the membrana granulosa take part in the formation of the corpus luteum, but it is more probable that they become detached and extruded shortly after the escape of the ovum. The characters of the cells of the yellow body, the vascularization of its tissue, and its subsequent blending with the general ovarial stroma, are all facts which point to the derivation of the corpus luteum from the wall of the follicle rather than from the epithelium which forms the membrana granulosa.

Vessels and nerves of the ovaries and Fallopian tubes.—The ovaries are mainly directly supplied by the *ovarian arteries*, analogous to the spermatic in the male, which anastomose freely by an internal branch with the termination of the uterine arteries. Sometimes this anastomotic branch is so large that the ovary seems to be supplied almost entirely by the uterine artery. The ovarian artery always sends numerous branches to the Fallopian tube. The smaller arteries penetrate the ovary along its attached border, pierce the proper coat, and run in flexuous parallel lines through its substance. The *veins* correspond, forming a plexus near the ovary named the *pampiniform plexus*. The *nerves* are derived from the *ovarian plexus*; and also from the uterine nerves, which invariably send offsets to the Fallopian tubes.

Parovarium.—The organ so named by Kobelt, or the Organ of Rosenmüller its first describer, is a structure which can usually be brought plainly into view by holding against the light the fold of peritoneum between the ovary and Fallopian tube (see fig. 608, po). It consists of a group of scattered tubules lying

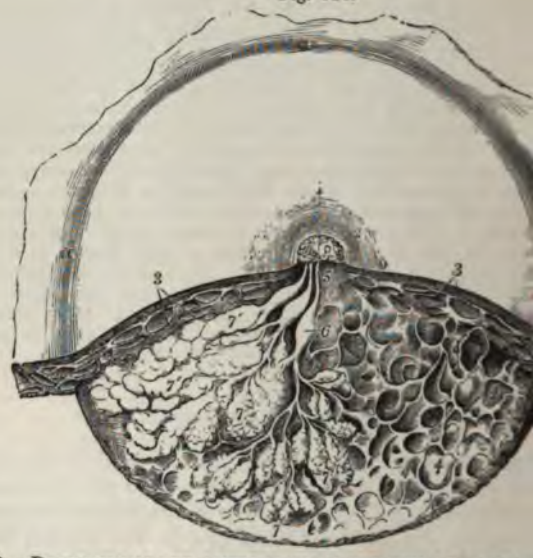
ersely between the Fallopian tube and ovary, lined with epithelium, but no external openings. The tubules converge towards their ovarian end, main separate there, while at the other they are more or less distinctly by a longitudinal tube which is sometimes of considerable size, and ed for some distance downwards in the broad ligament. Its more ed form in some animals, as the cow and pig, constitutes the duct of er. The origin of this vestige of a fœtal structure will be more fully l to under Development. Here it is sufficient to state that it corresponds lly to the epididymis of the male. Vestiges of the organ of Giraldès are metimes to be detected in the adult female, in the shape of tubular rem- situated in the broad ligament nearer to the uterus than the parovarium.

nt Literature.—Of the Ovary:—*Waldeyer*, Eierstock u. Ei, Leipzig, 1870, t. in Stricker's Handbook, 1871; *Romiti*, in Arch. f. mikr. Anat. X. 1873; , in Wurzb. Verhandl., 1874; *Foulis*, in Trans. R. S. Edinb., 1874. and J. of XIII., 1879; *Call & Exner*, in Wien. Sitzungsb., 1874 (Graaf. foll. and corp. lut.); sky, in Arch. de physiol., 1874 (str. and retrogr. of Graaf. foll.) and Annales de X. 1878; *Exner & Buckel*, in Wien. Sitzungsb., 1874 (lymphatics); *Born*, in A. , 1874 (ovary of horse); *Elischer*, in Med. Centralbl., 1876 (nerves); *de Sinéty*, tes rend. LXXXV., 1877; *Beulin*, Diss., Königsb. 1877 (corp. lut.); *H. Beigel*, in Gyn., XIII. (corp. lut.); *Kisch*, in Arch. f. Gyn., XII. 1878 (changes in Graaf. age); *Balfour*, in Quart. Micr. Journ. XVIII., 1878; *Wagener*, in Arch. f. 1879; *Paladino*, in Gior. intern. d. sci. med., 1879 and 1880 (corp. lut.); , in Arch. de biol., I. 1880; *v. Beneden*, in the same; *Schäfer*, in Proc. R. S. 1880; *v. Brunn*, in Gött. Nachr., 1880 (retrogr. of ova); *Cadiat*, in Journ. de 1881; *Schulin*, in Arch. f. mikr. Anat. 1881; *His*, Lage der Eierstöcke, Arch. , 1881; *Kölliker*, Lage d. weibl. inneren Geschlechtsorgane, Bonn, 1882.
he Discharge of Ova:—*J. Williams*, in Pr. R. S. XXIII., 1874; *Hennig*, in Sitzungsb., 1878; *Galabin*, in Obstetr. Journ., 1879; *Pinner*, in Arch. f. u.) Physiol., 1880; *Leopold*, in Arch. f. Gyn., XVI., 1880.

MAMMARY GLANDS.

mammary glands (mammæ), which yield the milk in the female, cessory parts to the reproductive system. They give a name to a class of animals (Mammalia), which are distinguished by the pos- n of these organs. When fully developed in the human female, orm, together with the integuments and a considerable quantity , two rounded eminences (the breasts) placed one at each side on ront of the thorax. These extend from the third to the sixth or th rib, and from the side of the sternum to the axilla. A little the centre of each breast, on a level with the fourth rib, or ly lower, projects a small conical body named the *nipple* (mammilla), points somewhat outwards and upwards. The surface of the is dark, and around it there is a coloured circle or *areola*, within the skin is also of a darker tinge than elsewhere. In the virgin, parts are of a rosy pink colour, differing somewhat according to omplexion of the individual, but they are always darker in women ave borne children. Even in the second month of the first preg- , the areola begins to enlarge and acquire a darker tinge; these es go on increasing as gestation advances, and are regarded as to be relied on in judging of suspected pregnancy. After lactation r, the dark colour subsides, but never entirely disappears. The f the nipple is marked with many wrinkles, and is covered with e; besides this, it is perforated at the tip by numerous foramina, are the openings of the lactiferous ducts: and near its base, as upon the surface of the areola, there are scattered rounded ele- s, which are caused by the presence of little glands with branched

Fig. 616.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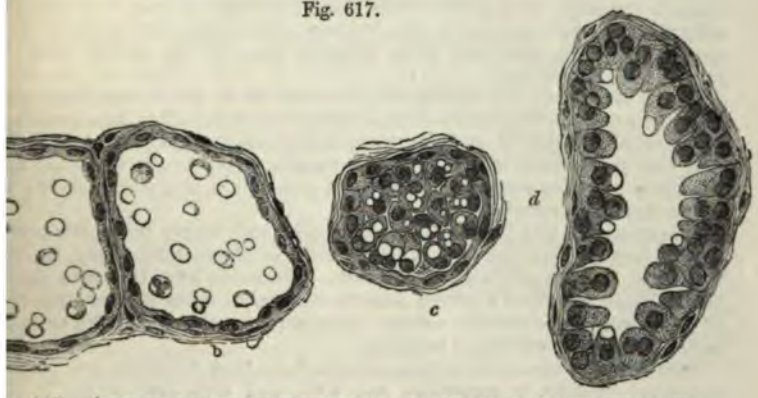
7
7

naller lobes, and these again into smaller and smaller lobules, which ttened or polyhedral, and are united by areolar tissue, blood-vessels, cts. The interlobular tissue contains numerous plasma-cells. The ace of the lobules is of a pale reddish cream-colour, contrasting with jacent fat, and is rather firm. The excretory ducts, named the *phorous ducts*, are from fifteen to twenty in number; they con- owards the areola, beneath which they become considerably dilated, lly during lactation, so as to form *ampullæ* or *sinuses* $\frac{1}{6}$th to $\frac{1}{4}$th inch wide, which serve as small temporary reservoirs for the milk. base of the nipple all these ducts, again reduced in size, are as- d together, those in the centre being the largest, and then proceed, side, surrounded by areolar tissue and vessels, and without com-

Fig. 617.



617.—ALVEOLI OF THE MAMMARY GLAND OF THE BITCH UNDER DIFFERENT CONDITIONS OF ACTIVITY (Heidenhain).

section through the middle of two alveoli at the commencement of lactation, the um cells being seen in profile; *c*, part of the wall of an alveolus in a similar con- with the epithelium cells seen flat; *d*, an alveolus in full secretory activity.

ating with each other, to the summit of the mamilla, where they by separate orifices; these orifices are seated in little depressions, re smaller than the ducts. The walls of the ducts are composed olar tissue, with longitudinal and circular elastic fibres. Both the nal vesicles and the ducts are lined with a simple layer of epithelium, passes into stratified near the external openings on the nipple.

e membrana propria of the alveoli appears to consist of a homo- us membrane having stellæ and anastomosing cells upon its inner e next to the epithelium.

e epithelium differs in its appearance according to the state of ty of the gland. When entirely inactive the alveoli are very small, he epithelium cells small and granular. At the commencement of tion the alveoli enlarge and become distended with clear secretion 617, *a*, *b*); the cells are flattened out against the membrana propria ontain fat globules of varying size and in the fluid contents of the li besides similar fat globules, some of which have a partial surround- f protoplasm, a few uni- or multi-nucleated granular cells are seen. ng full activity the cells become cubical or even columnar, but are ular in size and *exhibit indications* of division and of budding off

into the interior of the alveoli (fig. 617, *d*). By the breaking
the cells which have thus become free in the alveoli the constit
the milk appear to be formed, the fat globules which were presen
the cells becoming suspended in the fluid of the alveoli as milk
and the albuminous constituents of the cells becoming dissol
forming the casein and other proteid substances of the milk.

There is a rich network of blood-capillaries investing the alv
these are also surrounded by lymph-sinuses like those met with
racemose glands.

Difference according to sex.—The mamma begins to be formed a
the fourth month of fœtal life, but its subsequent growth is comparativ
At the third or fourth year of infancy, there is little or no difference in
female children. The fuller development of the gland in the female oc
towards puberty. It is probable that during the later periods of pregn
only do the alveoli increase in size, but new alveoli may bud laterally
pre-existing ones, and that after lactation some of the alveoli ma
atrophied and disappear.

In the adult male the mammary gland and all its parts exist, but q
rudimentary state, the gland itself measuring only from half to three quar
inch across, and $\frac{1}{6}$th of an inch thick, instead of four inches and a h
and one and a half thick, as in the female. Occasionally the male
especially in young subjects, enlarges and gives out a thin watery fluid
rare cases, it has secreted milk.

Blood-vessels and Nerves.—The **arteries** which supply the mamma
are the *long thoracic* and some other branches of the axillary artery, th
mammary, and the subjacent *intercostals*. The **veins** have the same d
tion. Haller described a sort of anastomotic venous circle surrounding
of the nipple as the *circulus venosus*. The **nerves** proceed from the ant
middle *intercostal* cutaneous branches.

Varieties.—Two or even three nipples have been found on one gl
additional mamma is sometimes met with, and even four or five h
observed to co-exist; the supernumerary glands being most frequently
ordinary pair, but sometimes in a distant part of the body, as the axil
or back.

Milk.—The milk is characterized by containing an immense numb
globules of varying size but averaging from $\frac{1}{1500}$th to $\frac{1}{3000}$th of a
diameter. They appear to be coated with an exceedingly thin inve
albuminous substance, probably casein, which prevents them from runn
ther into larger drops. but when this is dissolved by the addition of an
readily blend with one another. Rarely there is a more distinct,
partial, envelope of granular substance, occasionally containing a nuc
free nuclei have also been described as existing to a small extent in the

The mammary gland before and during the first two or three days a
turition yields a small amount of a turbid fluid termed the *colostru*
contains besides milk-globules single and in groups, amœboid cells, c

Fig. 618.

Fig. 618.—Constituents of the colostrum (Hei

a, *b*, colostrum-corpuscles with fine and coarse f
respectively; *c*, *d*, *e*, pale cells devoid of fat globules.

small or large fat-globules, either closely pack
the cell, or but few in number, or even absent a
and in the latter case permitting the nucleus to
(fig. 618). These amœboid cells are known as th
trum-corpuscles" (granular corpuscles of Donné): they occur either not
but very rarely, when the gland is in full activity. It is uncertain whe
originate as separated epithelium-cells of the alveoli, or whether
emigrated white corpuscles.

ırature.—On the structure of the mammæ :—*Langer*, in Stricker's
v. Brunn, in Gött. Nachr., 1874 (interstitial tissue) ; *Coyne*, Soc. d. biol.,
sinuses) ; *Winkler*, in Dresden Jahresb., 1874, and A. f. Gynäk. XI.,
tow, in Virch. Arch., 1877 ; *Schmid*, Z. Lehre v. d. Milchsecr., Wurzb.,
, in Gaz. méd., 1877 ; *Creighton*, Privy Council Reports, 1875, and Jour.
Kölliker, in Wurzb. Verhandl., XIV., 1879: *Rauber*, Ursprung d. Milch,
artsch, Diss., Breslau, 1880 ; *Sorgius*, Diss., Strasburg, 1880 (lymphatics);
ticle "Milch-Absonderung," in Hermann's Handb., 1880.
mamma :—*W. Gruber*, St. Petersb. Mem., 1866.
erary nipples and mammæ :—*Gegenbaur*, in Jena Zeitschr., VII. ;
ce, in J. of Anat. & Phys. XIII., 1879.
scopic elements of the milk :—*Schwalbe*, in Arch. f. mikr. Anat., VIII.
y, in Arch. de physiol., 1874 ; *Fleischmann*, "Das Molkereiwesen,"
5 ; *Schmid*, Op. cit., 1877 ; *Bouchut*, in Compt. rend., 1877 (numeration
idenhain, Op. cit., 1880.

THE PERITONEUM.

minal viscera having been described, as well as the dis-
he peritoneum in relation to each of them, it remains to
unt of that membrane in its whole extent, and to trace its
er the various parts which it lines or covers.

g the anterior wall of the abdomen, the peritoneum passes
h side to the lumbar region, where it meets with the right
ons of the large intestine. On the right side it completely
lower rounded end of the cæcum with the vermiform
at the rest of the cæcum it covers only before and on the
of the bowel behind, of variable extent, being immediately
he iliac fascia, except in rare instances where the membrane
round and forms a mesocæcum. It is disposed in a similar
he ascending colon, which is in immediate apposition with
l wall ; although here, too, the investment may be complete
ng right mesocolon.

he right colon, the peritoneum gives a scanty covering to the
the anterior face of the right kidney and adjoining third
e duodenum where that intestine comes down from behind
e mesocolon ; lower down it continues over muscles and
root of the mesentery, proceeds forwards to form the right
process, passes round the jejunum and ileum, affording them
al coat, and returns back to the vertebræ, thus completing
on the left side. The membrane now passes in front of the
of the left kidney, to the left colon, which it invests much
manner as the right, and is then continued over the lateral
left side to the front again, thus completing a horizontal
he abdomen. Where the colon forms its sigmoid flexure
ely invested by peritoneum, which attaches it by a com-
e and moveable sigmoid mesocolon to the fascia of the

part, and from the lower end of the mesentery the peri-
tinued into the pelvis. It there invests the upper part of
mpletely, forming a mesorectum behind. Lower down the
adually quits the intestine, first behind, then at the sides,
front, whence it is reflected on the base and upper part of
the male, and forms here the *recto-vesical pouch*, the mouth
ounded by a crescentic fold on each side, named *plica semi-*
m the apex of the bladder the peritoneum passes to the

back of the recti muscles. Here it covers the remains of the m

Fig. 619.

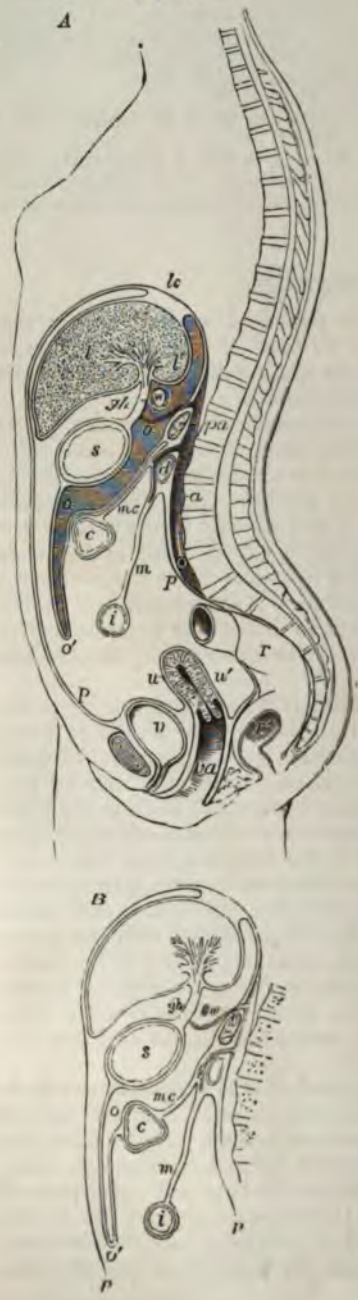


Fig. 619, A.—DIAGRAMMATIC OUTL
SUPPOSED SECTION OF THE BODY,
THE INFLECTIONS OF THE PERITO
THE FEMALE (Allen Thomson).

The upper part of the section is
the right of the mesial plane of t
through the quadrate and Spigelian
the liver below, it is supposed to be
l c, placed above the diaphragm op
the coronary ligament of the liver;
l', lobe of Spiegel; *s*, stomach;
verse colon; *i*, small intestine;
creas; *a*, aorta; *d*, duodenum;
bladder; *u*, uterus; *r*, rectum;
lower part opened; *v a*, vagina;
parietal peritoneum lining the
back of the abdominal cavity;
representing the inflections of the
sac of the peritoneum will be trac
the neighbourhood of *l c*, where
from the diaphragm to the upper
the liver, over the upper and lower
of that organ, in the front of *g h*, th
hepatic omentum, over the front
stomach, down to *o'*, the outer lay
great omentum; thence it passes
the vicinity of the pancreas, and
again as the upper layer of the t
mesocolon; after enclosing the
returns on the lower surface of t
verse mesocolon, *m c*, to the ro
mesentery, *m*; it now forms the
and encloses the small intestine,
to the posterior wall of the abdom
it passes over the rectum, *r*, des
the recto-vaginal pouch, *u'*, cover
and front of the uterus and the bl
tially, and regains the anterior
wall above the pubis. In conne
the lesser sac of the peritoneum
the position of the foramen of
if seen beyond the section; the
with the cavity of the omentum
with horizontal lines, and is m
round this space the line of the
may be traced from the diaph
the lobe of Spiegel, to the b
gastro-hepatic omentum, thence
stomach and down into the great
it then ascends to the pancr
it covers, and thence reaches
diaphragm.

B is a sketch of part of a sec
to that of A, but showing the
commonly taken, according to
two layers of the mesocolon are
with the posterior pair of the l
great omentum.

in the median line, and
literated hypogastric a
each side, which as

the bladder to the abdominal wall raises the peritoneum into a marked fold, separating two shallow pits named *internal and external inguinal pouches* (more fully described with the special anatomy of the groin). In the female the peritoneum passes from the rectum to the upper part of the vagina, and over the posterior and anterior surfaces of the uterus, whence it goes to the bladder. The *recto-vaginal pouch* (pouch of Douglas), like the recto-vesical, is bounded on each side by its semilunar folds, and the uterine peritoneum forms at the sides the broad ligaments of the uterus, along the upper border of which the Fallopian tubes receive from it a serous covering; but at their fimbriated openings the peritoneum is continuous with the mucous membrane of the tubes.

The peritoneum, on being traced to the upper part of the abdomen, is found to line the vault of the diaphragm, adhering moderately to the muscular and firmly to the tendinous part, and continuing down behind the liver as the hinder surface of the liver and the œsophageal opening. Then passes forwards on to the liver, forming the falciform, coronary, and lateral ligaments of that organ, already specially described.

Turning round the anterior border it passes back on the under surface; but, after covering the quadrate lobe, and arriving at the transverse fissure, it meets with a peritoneal layer from behind, and in association with it, stretches from the liver to the stomach, to form the lesser omentum, as will be presently explained. To the right of this it invests the gall-bladder, more or less completely, and the under surface of the right lobe of the liver, covers anteriorly the adjacent part of the duodenum, and passes to the upper end of the right kidney, forming here a slight fold, named *hepato-renal ligament*. It then invests the hepatic flexure of the colon, and reaches the right colon, on which it has been already traced. To the left of the longitudinal fissure the peritoneum invests the whole of the left lobe of the liver, and stretches across as the long left lateral ligament above and beyond the œsophageal opening. It then passes down over that opening and covers the front of the left side of the gullet, spreads over the left end of the stomach, before it passes off to invest the spleen, forming a duplicature named the *gastro-splenic ligament*, or *gastro-splenic omentum*, for it is connected below with the great omentum, and often reckoned as a part of it. Then the membrane passes from the diaphragm to the stomach it forms a small duplicature to the left of the œsophagus, named the *gastro-phrenic ligament*; it extends also as a generally stout and well marked fold (the gastro- or *phreno-colic ligament*) from the diaphragm opposite the tenth and eleventh ribs to the splenic flexure of the colon, then passes over the splenic flexure, and reaches the left kidney and descending colon, where it has been already described.

Omenta.—The arrangement of the remaining part of the peritoneum—that between the stomach, liver, and transverse colon—is somewhat complex, in consequence of the membrane forming in this situation a second and smaller sac, which communicates towards the right with the general cavity by a narrow throat, named the *foramen of Winslow*. This passage, which readily admits a finger, is situate behind the bundle of hepatic vessels which stretches between the liver and duodenum; behind the orifice is the vena cava; above is the caudate lobe of the liver; its lower boundary is formed by the duodenum and a curve of the hepatic artery. From this opening the lesser sac spreads out to the left

behind the general or main sac of the peritoneum. It covers a
the posterior abdominal wall, but in front and below it is applied
back of the main sac, to which it adheres except where the sto
interposed. Moreover, it indents, as it were, the back of the ma
and between the stomach and colon protrudes into it in form of
pouch—the bag of the omentum,—which thus has a double coat,
by the apposition of the membranes of both sacs. To trace this m
ment more particularly: suppose a finger pushed into the fora
Winslow, and the thumb brought to meet it from before, to the
the hepatic vessels; the membrane held between is double; its
layer (from the greater sac), turns round the hepatic vessels i
foramen, and then belongs to the lesser sac. The double membr
constituted, is the lesser or hepato-gastric omentum. From th

Fig. 620.

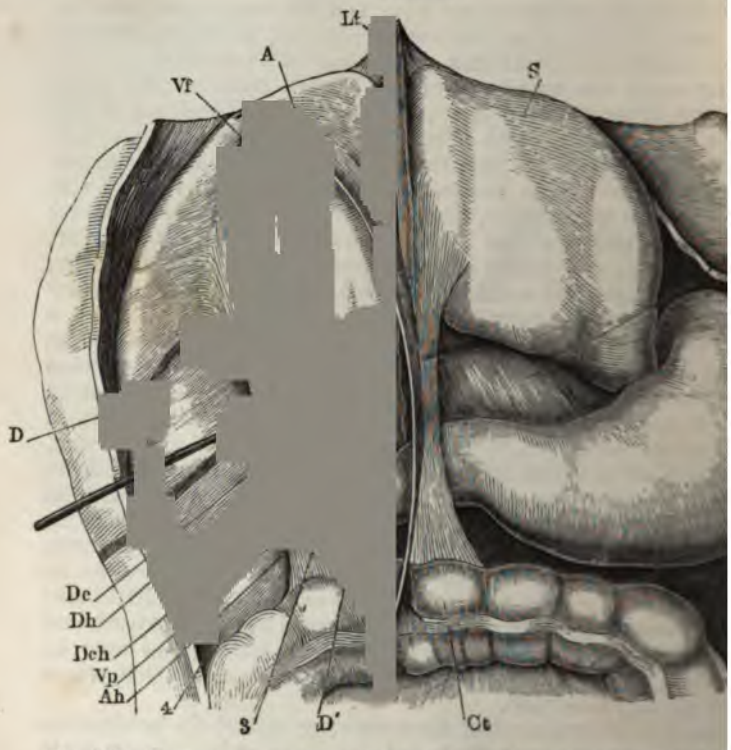


Fig. 620.—FRONT VIEW OF THE VISCERA OF THE UPPER PART OF THE ABD
CHILD (Henle).

The liver is drawn upwards in order to show its under surface and the smal
together with the entrance of the foramen of Winslow, into which a probe is
A, quadrate lobe of liver; S, left lobe; D, right lobe; Lt, ligamentum te
peritoneal covering forming the falciform ligament; V, stomach; Ct, transv
D', duodenum; 1, small omentum; 2, part of great omentum; 3, right p
omentum, its anterior layer being divided to show its contents, viz., Ah, hepa
Vp, portal vein; D ch, common bile duct; Dh, hepatic duct; and Dc, cystic
peritoneum reflected from the liver over the upper part of the right kidney,
renal ligament.

licated it may be followed to the transverse fissure of the liver, where laminæ separate, the anterior, which has already been traced from ove, spreading on the adjacent part of the liver, the posterior covering e Spigelian lobe, where it will be again met with. The attachment the combined layers continues backwards from the left end of the nsverse fissure along the fissure of the ductus venosus to the diaphragm which it runs a short way to reach the œsophagus, where the anterior mina covers the end of that tube in front and on the left, and the sterior lamina invests it on the right and behind. From this point, far as the pylorus, the small omentum is attached to the lesser cur- ture of the stomach, where its laminæ separate—one covering the terior and the other the posterior surface of the organ—but meeting ain at the great curvature, they pass down in conjunction to a variable stance before the small intestine to form the anterior part of the

Fig. 621.

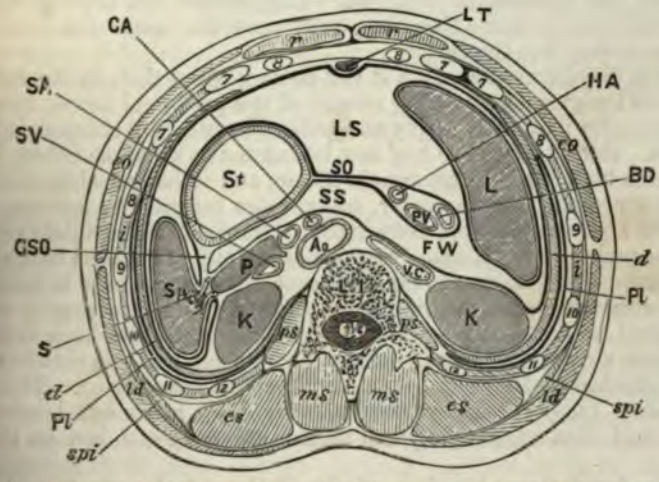


Fig. 621.—Diagram of a horizontal section through the abdomen at the level of the foramen of Winslow (R. J. Godlee).

L1, first lumbar vertebra; 12, 11, 10, &c., successive ribs; *r*, rectus muscle; *eo*, external oblique; *ld*, latissimus dorsi; *spi*, serratus posticus inferior; *i*, intercostal muscles; *es*, erector spinæ; *ms*, multifidus spinæ; *ps*, psoas; *d*, diaphragm.

Ao, aorta; V.C, inferior vena cava; C A, coronary artery; S A, splenic artery; S V, splenic vein; S, splenic vessels cut as they enter the spleen; H A, hepatic artery; P V, portal vein; B D, common bile duct.

L, liver; L T, ligamentum teres or round ligament of the liver; St, stomach; Sp, spleen; P, pancreas; K, kidney; LS, large sac of peritoneum; S S, small sac; S O, small omentum; G S O, gastro-splenic omentum; F W, foramen of Winslow; Pl, pleura.

The peritoneum is represented by a thick dark line. It can be traced from the middle line anteriorly, where it is seen investing the round ligament of the liver and forming the commencement of the falciform ligament, along the right side of the abdominal wall, over the front of the right kidney, to the inferior vena cava where it forms the posterior boundary of the foramen of Winslow; from the latter spot the small bag extends over the pancreas and left kidney nearly as far as the spleen, and then is reflected backwards along the back of the small omentum to the front of the foramen; here becoming large bag again, it turns round the hepatic vessels, forms the anterior layer of the small omentum, covers the front of the stomach, forms the gastro-splenic ligament or omentum as it is reflected on to the spleen, which it invests almost completely, and is thence continued along the diaphragm and abdominal wall back to the middle line.

great omental sac, and then turn up to form its posterior wall. Meeting next with the transverse colon, the two laminæ separate, and enclose that intestine, but meet again behind it to form the transverse meso-colon. This extends back to the lower border of the pancreas, from which its inferior layer is continued down over the posterior wall of the abdomen, and forms the mesentery, where it has been already recognised. The superior layer, on the other hand, which, as will be understood, belongs to the lesser sac, covers the front of the pancreas, the cœliac artery and its main divisions, the upper part of the left kidney, and the portion of the diaphragm between the aortic and caval orifices, and may extend to the left end of the pancreas and gastric surface of the spleen, partially investing the latter organ and forming part of the gastro-splenic omentum. It then goes forwards on the Spigelian lobe to the transverse fissure, and the line of attachment of the lesser omentum of which it then becomes the posterior layer. More to the right the layer in question passes over the vena cava, and continues into the general peritoneum beyond the foramen of Winslow. The gastric and hepatic arteries, especially the former (Huschke), may raise the membrane into folds which project into the cavity.

From the description given it will be understood that, as the sides or walls of the great omental bag consist of two peritoneal layers, its whole thickness (in its usually empty and collapsed state) will comprehend four layers. But although the bag may be inflated in its whole extent in the infantile body, its sides afterwards cohere, and it becomes impervious in its lower part. Fat, moreover, accumulates between its laminæ; long slender branches also pass down into it from the gastro-epiploic vessels.

The part of the membrane just described, which is attached to the great curvature of the stomach and transverse colon, and which is connected also with the gastro-splenic ligament (or omentum), is usually named the *great or gastro-colic omentum*. This may reach the hepatic flexure and pass a certain way down on the right colon, and this part has been distinguished by Haller and others as the *omentum colicum*. The great omentum (proper) usually reaches lower down at its left border, and it is said that omental inguinal herniæ are more common on the left side.

The description now given of the relation of the omentum to the mesocolon agrees with the appearances most frequently seen in the adult subject, and with the account usually given in English works of Anatomy; the exterior (here also posterior) layer of the great omentum being described as separating from the layer within, belonging to the omental sac, when it reaches the transverse colon so as to pass behind or below that viscus, and as proceeding thence backwards to the abdominal wall as the posterior or lower layer of the transverse meso-colon. It was, however, long ago pointed out by Haller, and the view has been confirmed by the observations of J. F. Meckel, J. Müller, Hansen, and Huschke, that in the fœtus, and occasionally in the child, or even in the adult, the two ascending layers of the omentum, though adherent to the transverse colon, may be separated from it and from the transverse meso-colon, proving that the transverse meso-colon is really a distinct duplicature of peritoneum. This view has been adopted by Holden and Luschka in their more recent works, and has been verified by Allen Thomson. Figures 619 A, and B, show diagrammatically the difference of the two views.

EMBRYOLOGY.

AND DEVELOPMENT OF THE BODY AND ITS ORGANS.

preceding parts of this work the anatomy of the body has bed chiefly in the adult or fully-formed condition. In the ection it is proposed to bring together the principal facts nown regarding the first origin of the human organism from and the successive changes of development in the embryo or vhich it attains its complete form and structure. As, however, dge derived from direct observation of the human ovum is ient for a detailed history of its development, more especially er stages, it will be necessary to refer frequently to the ng phenomena as ascertained to occur in mammals and birds, ı some other animals lower in the scale. In treating of this ention will be mainly given to the morphological view, the ıt of the textures having already been described in the histo- of this volume.

OVUM BEFORE EMBRYONIC DEVELOPMENT.

ıary object being the description of the origin and changes of elements out of which the new being is formed, we shall first he history of the ovarian ovum at the time when it is g maturity, and is about to leave the ovary, reserving the the origin of the ovum itself for a later part, when we shall eat of the special development of the reproductive organs. ext trace the changes of structure in the ovum which follow paration from the ovary and fecundation, and which result in ion of its more strictly germinal part, out of which, as an asis of formative material, the embryo is subsequently developed.

I. THE OVARIAN OVUM.

nan ovum, like that of mammals generally, is a compara- l spherical body of about $\frac{1}{125}$th or $\frac{1}{150}$th part of an inch r, and so long as it remains in the ovary, the seat of its is contained in one of the Graafian follicles of that organ. ne of maturation approaches, while the size of the ovum ery little increased, the follicle undergoes great enlarge- s to attain at last a diameter of one-sixth or one-quarter ı or even more. This enlargement is in great part due rease of the albuminoid fluid which occupies a large part erior; but it is of course also attended with a great multi-

een customary to make a distinction between the terms "embryo" and applying the first to the earlier and the second to the more advanced stages pment of the new organism; but although such a distinction may be con- not always maintained by authors, and the terms are sometimes used

plication and extension of the cells which constitute the so-called *tunica granulosa* surrounding the interior, and of the substance of the follicular wall itself. The ovum is imbedded in a thickened portion of the *tunica granulosa*, which since the time of Von Baer has received the name of *discus proligerus*, and is thus placed near the inside of the wall of the follicle; and when this most projecting part is fully developed, most frequently at the side next the surface of the ovary. But on this point observers differ, and at an earlier period especially it appears that the position of the ovum may vary greatly, and is not unfrequently on the deeper side of the follicle.

The small and almost microscopic body which constitutes the human ovum, like that of most mammals, which it closely resembles, possesses a very definite structure, which, as already partly explained in the Histology, is that of an organised animal cell. In this view of its nature, we recognise in it an enclosing cell-membrane or cell-wall, the protoplasmic and other contents, and among these the nucleus and nucleolus; corresponding more or less with parts which have been long familiarly known in the larger ova of birds and some other animals, under the names of yolk membrane, yolk or vitellus, germinal vesicle, and germinal spot.

As in all other animal cells, the main part of the cell substance of the ovum is essentially of the nature of protoplasm, but in the yolk the simple and homogeneous protoplasm is more or less mixed or associated with a different kind of substance, viz., the vitelline granules or corpuscles, which are not immediately or directly connected with the formative processes, but yet serve in a secondary or subsidiary way for the nourishment of the protoplasm and the parts developed out of it. Hence the distinction in most if not in all ova which has been recognised since it was made by Reichert in 1840 (No. 18), between the germinal or formative yolk substance and the nutritive or food yolk. It is mainly on the wide variation in the relative quantity and disposition of these two components of the ovicell that the great differences depend which are observable among the ova of different animals.

Different Forms of Ova.—The human ovum and that of mammals belong to a group of ova in which the proportion of food-yolk is very small, while that of birds, reptiles, and elasmobranch fishes is distinguished by the very large quantity of this material, as well as by the proportionally large size of the whole ovum. In the egg of birds the yolk (which alone is to be compared to the ovarian ovum of mammals) consists in great part of large vitelline corpuscles or spheroidal groups of granules, and the primary seat of embryonic development is limited to the small whitish spot called cicatricula, about $\frac{1}{8}$ of an inch in diameter, which lies close to the pedicle in the ovarian capsule, and in a newly laid egg on the side of the yolk which naturally floats uppermost. The germinal vesicle, which is of considerable size, $\frac{1}{75}$ to $\frac{1}{50}$th of an inch in diameter, lies embedded in the centre of the cicatricula so long as the yolk remains within its ovarian capsule, and it is to this part, composed of comparatively pure protoplasm, that the first changes connected with embryonic development are restricted. Thus the centre of the cicatricula and place of the germinal vesicle have come to be recognised as the upper or germinal pole of the egg, and to be distinguished from the opposite lower side of the yolk which may be termed the antigerminal or nutritive pole. So also it has been customary to distinguish such ova as those of birds by the term *meroblastic*, as

ting that a part only of the yolk is directly or primarily germinal
gaged in embryonic development. In the ovum of mammals, on
ther hand, the whole yolk undergoes from the first the formative
es which result in the production of an embryo, and such ova
hence been named *holoblastic*. But though the distinction here
oned is undoubtedly well founded and important, and the terms
d to the two most contrasting forms are so far appropriate, it
rs that the intermediate gradations and varieties in the relative
ity and disposition of the germinal and nutritive portions of the
are so numerous, that it is found impossible to make a complete
vision of the ova of animals according to this character.

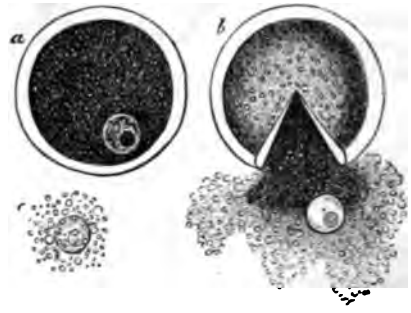
t while the mature ovarian ova of birds and mammals appear
st to differ very widely from each other, a comparison of inter-
ate forms and the observation of their earlier condition shows in a
ncing manner that they have essentially a homologous structure, and
notwithstanding the very large size and the apparent complexity of
ture in the egg of the bird, both kinds of ova have in common the
ntary form of the simple animal cell.

is obvious that the great difference in size between the avian and
mammalian ovum has reference to the mode of nutrition of the
yo in the progress of its development, as modified in the one case
he complete separation of the egg from the parent body, which
nitates the provision within it of all the nourishment required for
whole duration of incubation ; and in the other case by the de-
ent and attached condition of the ovum and its annexes which
les them to draw a supply of nutriment from the parent during the
e of gestation.

MAMMALIAN OVUM.

he Yolk Substance.—In the mammalian or human ovarian
a which is approaching maturity, the yolk substance forms a well-
ed spherical mass, completely filling the cavity of the containing
brane. The yolk is at no place perfectly clear or homogeneous, but
nits throughout a certain turbidity from minute granules imbedded
ne purer protoplasm. The amount of yolk granules, which varies
iderably in different animals, is small in the human ovum, and in
ral the granules are of smaller size and in less number near the

Fig. 622.



322.—Ovarian ovum of a marmiver. $\frac{250}{1}$. (A.T.)

the entire ovum, viewed under
ure ; the granular cells have been
ved from the outer surface, the
nal vesicle is seen in the yolk sub-
e within ; *b*, the external coat or
burst by increased pressure, the
protoplasm and the germinal vesicle
g escaped from within ; *c*, germi-
vesicle more freed from the yolk
ance. In all of them the macula
a.

ace of the yolk and in a space immediately surrounding the ger-
al vesicle. *The yolk granules*, or yolk corpuscles, as the larger may

be termed, are chiefly spherical in form, and are of the most various size, from the minutest molecules up to the diameter of $\frac{1}{100}$ or $\frac{1}{150}$th of an inch. They are different in composition from the clearer protoplasm, consisting mainly of protagon with fat and some other ingredients.

Fig. 623.

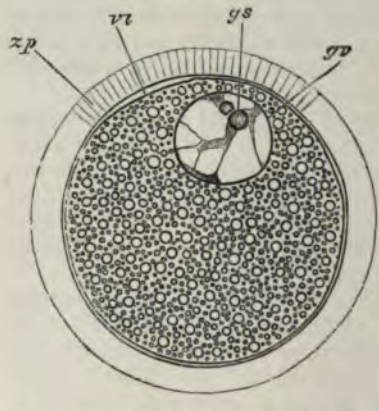


Fig. 623.—Ovum of the cat; highly magnified. Semi-diagrammatic. (E.A.S.)

zp, zona pellucida, showing radiated structure; *vt*, vitellus, round which a delicate membrane was seen; *gv*, germinal vesicle; *gs*, germinal spot.

They are enclosed in the substance of the more homogeneous protoplasm. The latter presents in the living state all the characters of this substance, sometimes exhibiting the finely radiated linear or fibrillar structure which belongs to its growing condition, and possessing the amœboid contractile property which is known to characterise most of its forms.

Germinal Vesicle.—While the protoplasm and vitelline granules constitute the main part of the cell-substance of the ovum, the germinal vesicle is an invariable constituent and forms its nucleus. In the ovum which has not yet arrived at complete maturity this body has a spheroidal shape, and consists of a matrix containing nucleoplasm enclosed in a fine but distinct homogeneous vesicular membrane, and is for the time situated in a clearer part of the yolk protoplasm near the surface on one side which thus becomes the germinal pole. Its size in mammals generally is about a fourth part of the diameter of the ovum, and therefore in the human ovum it may be about $\frac{1}{500}$th of an inch in diameter, being actually smaller but proportionally larger than in birds. The substance of the germinal vesicle corresponds in all respects with the usual contents of growing cell-nuclei, and may therefore be described as nucleoplasm.

Germinal Macula or Spot.—In mammals there is generally one principal nucleolus of a regular spherical or lenticular form, and presenting not unfrequently a well-defined outline. This is the macula germinativa of Rudolf Wagner, now generally recognised as corresponding to the cell-nucleolus. In mammals, however, as in other animals, the macula or nucleolus may be subdivided into several, of which one is usually larger than the rest; and in this one we may perceive an internal division into smaller opaque granules. The nucleolus appears, as in other cells, to consist mainly of a granular modification of the cellular nucleoplasm.

Zona Pellucida.—The most obvious enclosing membrane of the mammal's ovum is that already referred to as the zona pellucida,—a name given to it by Von Baer on account of the appearance which it presents, in a nearly ripe ovum extracted from a Graafian follicle, of a clear broad band lying between the opaque yolk substance within and the granular cells of the proligerous disc which adhere to it externally.

s vesicular envelope of the ovum is of considerable thickness and

624.—MATURE OVARIAN OVUM OF THE GUINEA-PIG (from Bischoff.) $\frac{350}{1}$

zona pellucida is hidden by the adherent the membrana granulosa, which have as- a pediculated form next its surface. The ranular yolk substance fills the cavity of a. The germinal vesicle has disappeared.

Fig. 624.

at strength, bursting only under pressure or by the aid of cutting ments. Under a moderate magni- power, when freed from the ad- t cells of the proligerous disc, it rs homogeneous; but when sub- l to higher magnifyers, such as 500 0 diameters, it frequently exhibits ar radiation through its thickness, which bears some resem- e to the more distinct radiated and porous structure in the overing of osseous fishes, insects, and some other animals. And are of opinion that the pores of the covering of the mammal's are capable of transmitting minute granules or even cells from terior into its cavity; but it seems probable that such a condition e pores is not constant, and that their occasional enlargement, as ved by Lindgren (No. 65) and Von Sehlen may depend upon tural circumstances (No. 66).

1841 Reichert described a second more delicate membrane as immediately nding the yolk substance in the mammal's ovum, and more recently Edw. eneden (No. 57) has affirmed the existence of such a membrane, and s to this opinion in the account of his latest researches (No. 63). This ane he finds to be formed in the mammal's ovum as it approaches maturity, remain visible for some time after it has left the ovary. F. M. Balfour 2 and 62) is inclined to adopt the same view, while other embryologists tertain doubts as to its existence.

1840 Barry thought he had discovered in the rabbit's ovum a distinct fora- perforation of the zona pellucida similar to the *micropyle* of fishes, and some other animals, and Pflüger and E. V. Beneden for a time ed this view. But the last observer has from his most recent observations d to abandon it, and as many other embryologists have sought in vain for erture, it may now with certainty be considered as absent from the mam- as ovum in the more distinct form described by Barry, although occasion- before stated, minute pores or radiating canals are seen to pierce the membrane.

Mammalian ovum was discovered by Von Baer in 1827 (No. 49). The al vesicle, which had been made known in Birds by Purkinje in 1825), was first described in the Mammal's ovum by Coste in 1833 (No. 50, i.), also been independently observed by Thomas W. Jones in 1834 (No. 51, i.). acula or nucleolus was first pointed out by Rudolph Wagner in 1835 , i. & ii.). See the Bibliography, Nos. 47 to 66.

ATURATION OF THE OVUM AND SEPARATION FROM THE OVARY.

as long known that at or near the time of the full maturation of um and its leaving the ovary, both in birds and mammals, the al vesicle, which had gradually approached the surface of the n ovum in the later stages of its development, finally disappeared lost *to view. It was not certain* however that this occurred in all

animals, nor was it known how the disappearance was to be explained and whether any part or how much of the substance of the germinal vesicle, as was vaguely conjectured, might have remained to undergo further changes, to combine with the yolk, or to form the basis of

Fig. 625.

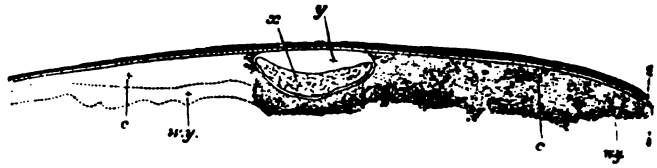


Fig. 625.—VERTICAL SECTION THROUGH THE GERMINAL DISC OF THE RIPE OVARIAN OVUM OF THE FOWL, IN ITS CAPSULE. (From Balfour.)

a, Connective tissue of the ovarian capsule; *b*, its epithelium, close to which is the vitelline membrane of the ovum; *c*, granular protoplasm which undergoes segmentation; *w.y*, white yolk substance; *x*, substance of the germinal vesicle shrivelled up; *y*, space left by this shrinking within the membrane of the vesicle.

embryonic nucleus. Improved modern methods of histological research have led to the discovery of some of the phenomena of retrogression of the germinal vesicle and the foundation of the germ of a very remarkable kind, of which a short account will be given at this place.

Exclusion of the Polar Globules, and Formation of the Female Pronucleus.—These phenomena of retrogression in the germinal

Fig. 626.

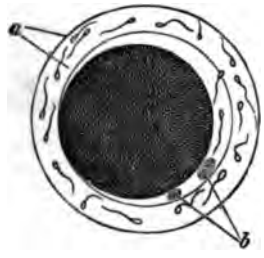


Fig. 626.—OVUM OF THE RABBIT FROM THE FALLOPIAN TUBE, TWELVE HOURS AFTER IMPREGNATION. (From Bischoff.)

In the zona *a*, spermatozoa are seen; *b*, two hyaline globules or polar bodies within the cavity left by the shrinking of the yolk.

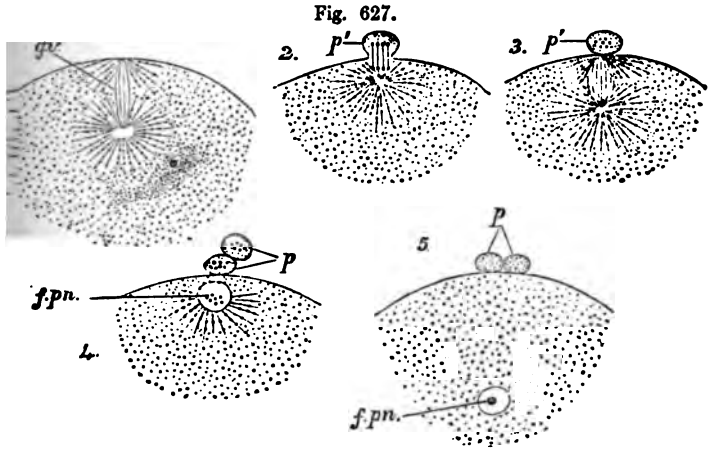
vesicle are intimately connected with another appearance which since its first discovery by Dumortier in 1837, and further investigation by F. Müller in 1848, has been familiar to embryologists in a very wide range of animals, viz., the formation or extrusion from the yolk at the time of complete maturation of the so-called *polar* or *directing* globules, of which the relation to the germinal vesicle has only recently received a more minute investigation, although various more or less probable suppositions had been from time to time formed as to their nature.

The most precise and satisfactory of the recent observations now referred to have been made chiefly upon the ova of animals comparatively low in the scale, but we are not without evidence that nearly similar phenomena occur also in the higher animals and especially in mammals. We shall first describe shortly the results of observations made by Bütschli, Fol, and Hertwig on the ova of some Echinoderms and Heteropods; referring the reader to the works quoted at p. 22 of this volume, and to the very clear account of the phenomena given by Balfour (No. 32, vol. i. p. 55, and No. 76).

In the Asterias glacialis, according to Fol, as soon as the ripe ovum

hed from the ovary and placed in sea water, the germinal vesicle, a was previously of a regular spherical shape and presented the ar reticulum and all the usual characteristics of such structures, its external membrane and its internal reticulum, takes an irregular ae and undefined structure, and becomes to some extent confounded the vitellus. The germinal macula also gradually disappears. een the remains of the germinal vesicle and the surface of the yolk now appears a nuclear spindle or double cone terminating ex-lly in a star-like arrangement of the protoplasm. Soon afterwards ner star appears and the nuclear spindle lies horizontally between

Fig. 627.



g. 627.—STAGES IN THE FORMATION OF THE POLAR GLOBULES IN THE OVUM OF A STAR-FISH (from Hertwig.)

erminal vesicle transformed into a spindle-shaped system of fibres ; *p'*, the first polar becoming extruded from the surface of the ovum ; *p*, polar globules completely ed ; *f.pn*, female pronucleus.

wo stars. Oscar Hertwig observed phenomena very nearly similar nother Echinoderm (Asteracanthion), but it was not determined by r of these sets of observations, what share, and whether any, the la took in the changes which occurred ; but further observations ol on one of the Heteropodes (Pterotrachæa) made it certain that metamorphosis of the germinal vesicle results in the formation of a ar spindle with the two stars lying near the surface of the ovum, that these phenomena, as was well known also in other animals, are independent of fecundation.

he next change consists in the spindle assuming a vertical instead of rizontal position, and in the subsequent projection of one end or in a protoplasmic prominence or knob from the surface of the yolk. constriction which follows in the outer part of this prominence, a l spherical mass of clear protoplasm constituting the *first polar body lobule* is separated and takes its place close to the original site of the inal vesicle in a space now formed by the shrinking of the yolk een the surface of that body and the enclosing membrane.

e process of nuclear division being repeated in the spindle-shaped , another polar globule is separated in a manner similar to the first,

protoplasm in a lenticular form. The germinal s
surface of this becomes discoid, while the memb
vesicle vanishes or unites with the disc. The
collects into a nucleoplasmic mass, and along w
remains for a short time within the ovum. Soo
a polar body is found outside the yolk, composed o
one stains deeply in the same manner as the disco
while the other resembles the nucleoplasmic sub
Van Beneden looks upon these parts of the polar
products of the germinal vesicle ; but Balfour cons
that a part of the germinal vesicle remains in t
female pronucleus.

The shrinking of the yolk coincides with the
polar body which usually takes place before the r
the second polar globule is more frequently expelle
entered the tube, and along with its appearance th
ing of the yolk ; but all these phenomena are
fecundation or any influence of the male sperm.

Separation from the Ovary.—It is now we
maturation and the discharge of the ovarian ova a
changes to which the Graafian follicles are subj
during the breeding period,—in the human fema
menstrual term, and in animals at the times of
changes take place independently of the influen
impregnation (Bischoff, No. 67).

In animals, such as the sheep or dog, when the state
days, and in the human female at or near the time of
ovum is discharged by the rupture of the thinner and m
Graafian follicle. The aperture takes place at a spot, the
is non-vascular, is small and with irregular or ragged ed
a solution of continuity of the tissue is preceded by inc
neighbourhood. The ovum in escaping remains imbedde

from its yellow colour *corpus luteum*, and it is important to observe es place in all cases of the rupture of a follicle, whether or not it owed by impregnation. The changes involved in the formation of d its structure have been already described at p. 336 of this volume.

III. FECUNDATION OF THE OVUM.

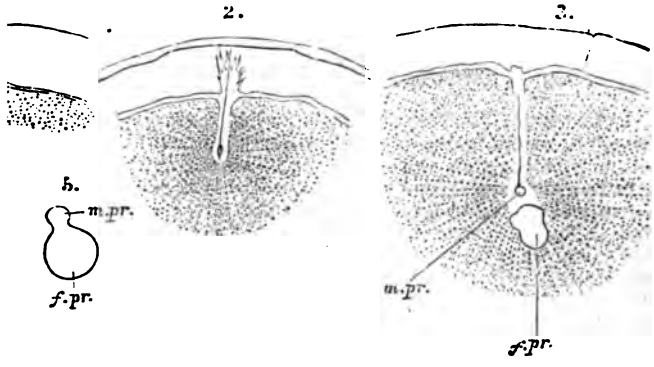
ess of fecundation, which will be considered here only in its the formation of the germ, consists, in its most general , essentially in the union of the male and female generative For the history of the male generative element we refer the ıe account given at p. 698 of this volume.

ıction of the Spermatozoa into the Ovum.—The fact ual entrance of spermatozoa within the zona or covering of iferous ovum was first observed by Martin Barry in 1843, gh his statement was received with considerable hesitation temporaries, it has since been repeatedly confirmed by the l careful investigation of many observers.

in animals the spermatozoa have been seen to enter the cavity ım by an obvious micropyle aperture, as first observed by fishes (No. 72), and by Meissner and Leuckart in insects; but ls and other animals in which no such aperture exists, it is arly understood in what manner the spermatozoa make their gh the consistent membrane of the ovum.

s in the Ovum and Spermatozoa giving rise to a onucleus.—In mammalia, although the spermatozoa are l to pass in numbers through the zona, they have not been

Fig. 628.



. 628.—FERTILIZATION OF THE OVUM OF AN ECHINODERM (Selenka.)

ıoon; *m.pr*, male pronucleus; *f.pr*, female pronucleus.
ın of a spermatozoon to the periphery of the vitellus; 2. Its penetration, and position of the vitelline granules; 3. Transformation of the head of the sper- › the male pronucleus; 4, 5. Blending of the male and female pronuclei

ı any case to penetrate or combine with the substance of the s extremely probable that such combination does take place, ly know of this occurrence by observations made on the lower hich, however, throw so much light on the whole process of ı that *it is proper to give* an account of them in this place.

One of the spermatozoa more advanced than the rest
surrounded and ultimately combined with a prominent
substance, and, the tail remaining motionless and sub
pearing, the head, or it may be some other part of the
now gathered together into the form of a nucleus, and,
depth into the substance of the yolk, becomes surro
radiated lines known to belong to such structures. It
converted into the *male pronucleus*.

**Fusion of the Male and Female Pronuclei, ar
of the First Segmentation Sphere.**—The male pron
approaches the site of the female pronucleus; and as
in contact with it, the latter, which was previously mot
a new activity, and the two pronuclei, impelled perhaps
movements of the yolk protoplasm which accompany th
unite or are fused into one.

The result of this union is the formation of the fi
segmentation sphere, or *Blastosphere*, which may be regar
ated protoplasmic cell, containing the products of the n
generative nuclei, or some portion of them, combined
protoplasm of the ovum.

In mammalia Van Beneden has shown that the first segmenta
its origin to the fusion of two previously existing nuclei wh
others than the male and female pronuclei. In Petromyzon,
and Benecke have demonstrated that a single spermatozoon
ovum, and the researches of Bambeke and Hertwig make it e
that in Amphibia similar phenomena attend the maturation a
the ovum, while Oscar Hertwig has traced in Echinus lividu
the spermatozoon into the ovum and its transformation into th
Precisely similar phenomena have been ascertained by Salens
sturgeon; so that there is good reason to believe them to be
bisexual animals. (See Balfour, No. 32 and No. 76.)

Differences in the details of these phenomena may occur in
more especially according as impregnation may take place b

since the similar origin of the generative elements of the two sexes has ascertained, it has been customary to regard fecundation as consisting ally in the union of the male and female generative cells: but we can now a much more definite idea to this view when we know that the act of ation consists in the fusion of a male and female pronucleus, of which one rung from the remains of a primitive ovicell, and the other is the product rimitive sperm cell, and that both of these have had their origin in similar ary structures of the parent while in the embryo stage of its existence. r, No. 32. Balbiani, No. 64, and Bibliogr. Nos. 67 to 76.)

EGMENTATION OF THE FECUNDATED OVUM, AND FORMATION OF THE BLASTODERM.

is a general fact among bisexual animals that within a very short after the fertilization of the ovum has been effected by the combina- of the sexual elements, the blastosphere or nucleated mass of pro- ve protoplasm which results from the act of union proceeds to go a process of division and multiplication after the manner of leavage, and by the ordinal repetition of that process for a con- able number of times there is eventually produced a collection of *meres* or nucleated cells, out of which the further development e embryo subsequently takes place. To this mass of cells capable mbryonic development the name of protembryo or primitive embryc t be applied, but it is the same which has been called *germinal rane* or *blastoderm* in the higher animals, because of the flattened minar form which the collection of its cells generally presents.

this process of cell division and multiplication in the fecundated the names of yolk cleavage, or more strictly germ-segmentation pplied. Though common to all the metazoa it presents many and variations in the different classes of animals, and even among some families. Here we must confine our attention mainly to those in which the phenomena tend to illustrate the process as it occurs mmalia.

ifferent Forms of Segmentation among Animals.—The more rtant of these varieties are obviously related to the difference in proportion of the nutritive and germinal material in the holo- ic, meroblastic, and intermediate forms of ova. In the case of mals, the whole mass of the yolk is subject to this change, or is diately involved in the process of cell division, while in the mero- ic ovum of the bird the first cleavage and consequent formation of stoderm is limited to that small portion of the yolk which is termed erminal disc or cicatricula, and which is alone the seat of the st phenomena of development.

is difference constitutes the distinction between *total* and *partial* entation, of which we shall have to consider more fully the pheno- , and with regard to which it is only necessary to say further at this that there is a close inverse relation between the extent of the enting process and the quantity of the nutritive yolk substance h is associated with the purer protoplasm of the ovum; and thus gh the amphibia and other animals, besides variations of other , all possible gradations are to be found in the proportion of the ance of the ovum which is primarily involved in the cell-forming ss resulting from segmentation.

e intermediate form of segmentation which occurs in the Amphibia, the frog or newt, is so instructive that it will be proper to introduce

neighbourhood of the first, which was the original seat of
and the larger quantity of nutritive yolk accumulated at
germinal pole. The accompanying diagram copied from Ecke
clear view of the successive steps of the process; 1 represe
condition, 2 the first vertical cleft which divides the wh
indicates the stage at which by a second vertical cleft the
into four segments. In these two first stages the vertical
wards from the upper or germinal pole, where they cross

Fig. 629.

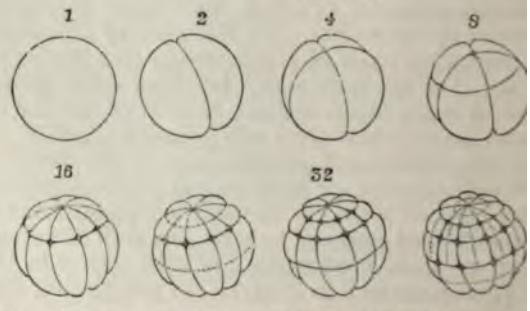


Fig. 629.—UNEQUAL SEGMENTATION IN THE EGG OF THE FROG (from

Ten stages are represented; the numbers over certain figures i
segments at each of these stages; in the intervening figures the fis
formation.

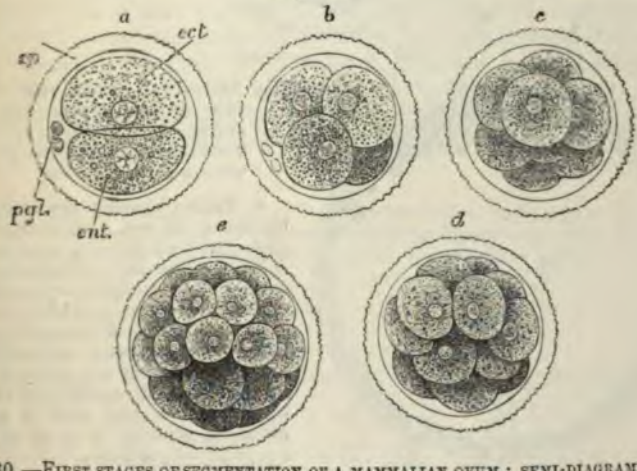
angles, to the lower or nutritive pole. In the next stage, ho
which that number of segments have appeared, the new cle
parallel to the equator of the sphere, but at some distance a
is succeeded by radial or meridional clefts which, proceeding
germinal pole, divide first the upper and later the lower segm
duce first twelve and later sixteen segments, as seen in the
Two equatorial clefts follow, which have the effect of divi
and lower meridional segments, so as to produce first 24
segments; and by a succession of similar alternating ver
clefts a greater and greater multiplication takes place, but i
give rise to more numerous and smaller and closer cells i

animals, but among the vertebrates or animals allied to them the only ples are those of Amphioxus and Petromyzon. In the case of Amphioxus the successive reduplication of the yolk-spheres has proceeded to such an t as to divide the whole into smaller uniform nucleated cells, these cells are to have arranged themselves as a layer on the surface, while the interior is ied by fluid, constituting thus a cellular vesicle with a segmentation cavity n; and the first change which succeeds to this stage consists in the doubling invagination of one side of the cellular wall so as to give rise to a secondary y communicating with the exterior, while the two sides approach one ner so as gradually to narrow and at last obliterate the original cavity which etween them. The part which remains outside forms the external layer or erm, and that which is doubled in is the internal layer or entoderm. The mbryo or blastoderm thus assumes the form of the bilaminar *gastrula* of kel, communicating with the exterior by the now narrowed aperture called opore, and representing in fact the simplest form of an alimentary cavity.

omplete Segmentation in Mammals.—The Mammals come to the Amphioxus in the completeness and regularity of the segtation, but they differ from it both in the early distinction of the er and lower blastodermic cells and in the absence of any obvious gination of the vesicular blastoderm.

he segmentation of the mammiferous ovum had been seen by Martin y, but its general features were first clearly demonstrated by the imant researches of Bischoff. In more recent times much light has

Fig. 630.



630.—First stages of segmentation of a mammalian ovum: semi-diagrammatic. (Drawn by A. T. after Edwd. v. Beneden's description.)

, zona pellucida; *p.gl*, polar globules; *ect*, ectomere; *ent*, entomere; *a*, division two blastomeres; *b*, stage of four blastomeres; *c*, eight blastomeres, the ectomeres ally enclosing the entomeres; *d.e*, succeeding stages of segmentation showing the more division of the ectomeres and the enclosure of the entomeres by them.

thrown upon the nature of this process by the interesting researches Edwd. Van Beneden (No. 74) and others. From the observations an Beneden it appears that in the ovum of the rabbit within one or hours after the union of the male and female pronuclei the process ivision of the nucleus and the primary segment sphere commences.

This, as well as all the subsequent divisions which occur, is accon by the usual phenomena of spindle modification of the nucleus an striation of the surrounding yolk protoplasm. The whole pr segmentation is accomplished in the rabbit within from 70 to 7 after fecundation, by which time the ova have passed through lopian tubes and are entering the cavity of the uterus.

The principal phenomena as described by Van Beneden are as First a complete division of the whole yolk into two spheroidal masses takes place, the cleft seeming to depart from the place p occupied by the polar or directing bodies. Each of these sph next divided in a similar manner with the first into two, so result, and in a third stage the division of the four spheres ha

Fig. 631.

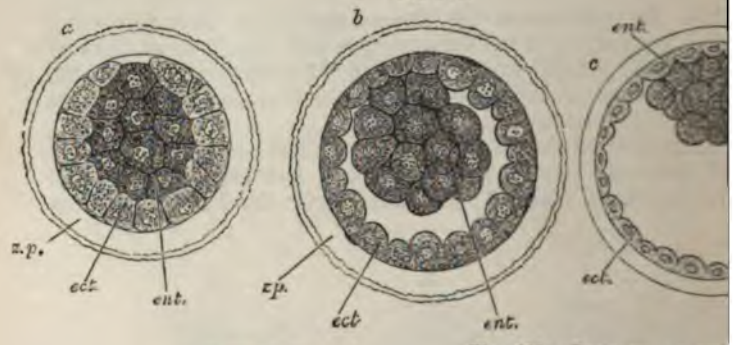


Fig. 631.—Sections of the THE RABBIT DURING T STAGES OF SEGMENTATION THE FORMATION OF THE BL VESICLE (E. v. Beneden).

a, Section showing the e entomeres by ectomeres exc spot—the blastopore; *b*, mor stage in which fluid is begin cumulate between the entomer meres, the former completely *c*, the fluid has much increase large space separates ento ectomeres except at one part dermic vesicle, its wall forme of ectodermic cells, with entomeres adhering to it at *z.p.*, *ect.*, *ent.*, as before.

number up to eight. It is to be remarked however that the s two spheres resulting from the first cleavage is not equal, bu which we shall call the upper is the largest, and it is also differently affected by reagents from the lower one; and Van has suggested the view that this difference is already an indic distinction between the cells of the upper and lower laye blastoderm (Nos. 74 and 75).

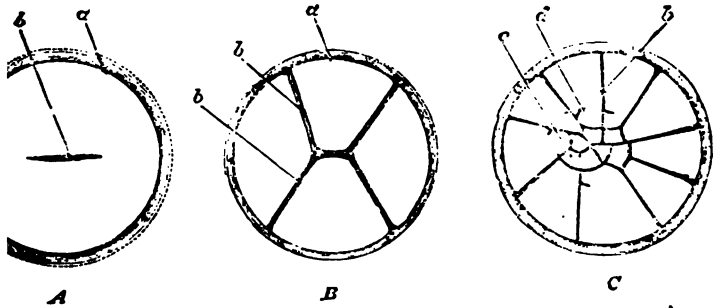
When the division has reached the third stage and eight sp formed, these are found to have arranged themselves in such that the four lower cells become more closely gathered toget

m taking a central position with reference to the rest, and the four cells at the same time show a tendency to surround and enclose wer, which at a later period their successors do more completely. lifference in the rate of division of the upper and lower group of es now becomes apparent, that of the upper being somewhat in ice of the lower; and thus in the fourth stage, while the cells i lower group remain only four in number, the upper have divided mount to eight. The division of the lower group then brings number to eight and the whole yolk consists of sixteen spheres. ere is now found also to be a change in the relative size of the and lower groups of spheres, the latter having now become the and fewer, and also the more opaque and granular in their aspect. e upper spheres at the same time show more and more tendency read over the surface of the lower group which are gathered to- in a ball, and thus to surround and enclose them. This enclosure, ver, is not complete till the tenth stage, when the whole number heres, or cells as they may now be called, is 96, of which 64 are of the surface, and 32 occupy the interior.

re is a time however during which the external layer of cells, h covering the mass of inner ones, does not completely close them t leaves one or more of them visible by an aperture which has been ured by Van Beneden, but according to some on insufficient grounds, blastopore or aperture of invagination in the lower animals. This ure is soon effaced by the union of the external cells over it, and in tage, which may be regarded as the completion of the segmentation, um is covered externally by an entire layer of nucleated and some- prismatic cells, while the interior is occupied by a solid mass of of a different character. Thus the whole segmented ovum, which l only slightly increased in size, is converted into a hollow cellular to which at a later period the name of *blastodermic vesicle* is

dial Segmentation.—The process of segmentation as it occurs in meso- ova contrasts widely in its more apparent phenomena with that pre- described, and yet, considered as one of protoplasmic cell-division, and

Fig. 632.



2.—SURFACE VIEWS OF THREE EARLY STAGES OF SEGMENTATION IN THE FOWL'S EGG. (From Balfour after Coste).

ge of the Primary furrow; B, first Radial furrows; C, other Radial furrows with circular; *a*, edge of the germinal disc; *b*, primary and vertical furrows; *c*, smaller and *d*, larger peripheral segments.

viewed in the light of the relations of its germinal and nutritive yolk subst each other in the ovum, the phenomena may be regarded as functio similar. In the egg of the bird, as in the common fowl, the primary se tion of the germ is limited to the cicatricula or germinal disc, and this is accomplished during the descent of the yolk or ovarian ovum thro oviduct, and particularly in its lower part, while at the same time the

Fig. 633.

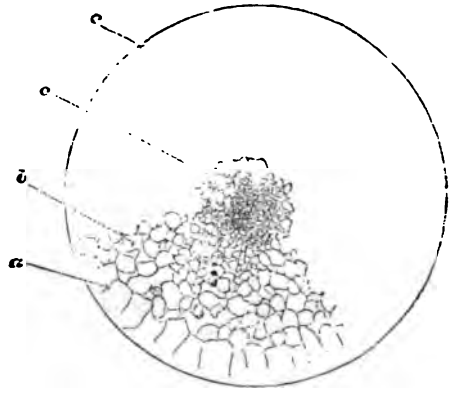


Fig. 633.—Surface view GERMINAL DISC OF TH EGG IN A LATER STAGE MENTATION (from Ba

c, small central segm spheres; *b*, larger segme side these; *a*, large, im circumscribed, marginal se *c*, margin of the germinal

being enclosed in its a constituents of albumen brane, and shell deriv secretion previous to it laid. This descent occupies in the comm from 16 to 24 hours or m longer period, and the of segmentation is the comparatively rapid on

The more obvious phenomena attending this process, as observed (No. 22, iii.) and Kölliker (No. 28 i. p. 70), consist in the occurrence, first of or cleft across the cicatricula in a determinate direction, which appears right angles to the long axis of the whole egg. This is soon followed by groove, which crosses the first nearly at right angles or intersects it at sides in two separate places. In a third stage the four segments of the

Fig. 634.

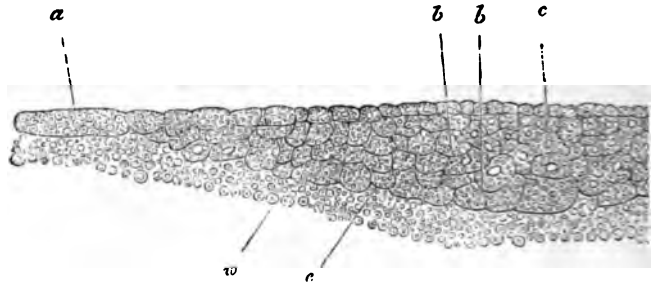


Fig. 634.—Vertical section through more than a half of the germin A fowl in the later stages of segmentation (from Balfour.)

c, indicates the middle of the germinal disc; *a*, one of the larger peripher *b*, larger cells in the deeper part of the blastoderm; *c*, edge of the blastoder the white yolk (*w*); most of the cells contain nuclei.

disc which were separated by the two first grooves, are again divid grooves, each of which, like the first, has a radial disposition, so segments now result. But in a fourth stage the segmenting groove t cular or concentric direction, and is such as to cut off a small por upper angle of each of the eight radial segments close to the centr

its are thus formed, and subsequently, by a less regular alternating
ion of radial and concentric division the whole disc comes to be divided
naller portions, within each of which, as appears in the end, a nucleus is
, and which therefore have the value of true protoplasmic cells. They
fact the precursors of the formative cells of the blastoderm. It appears
that the cells which thus result from the segmenting process are
ed in two layers, an upper consisting mainly of one range of cells which
arer and with more defined outlines, and a lower set of cells, which are
hat larger, more opaque and granular in their aspect and more loosely
egularly disposed. These layers are separated from the yolk below by a
which may be called the segmentation cavity, and they correspond with
mitive layers of the blastoderm.
nature of the meroblastic form of segmentation now described was first
understood from the observations of Kölliker on Cephalopoda in 1844;
e phenomena have since been investigated in reptiles, cartilaginous fishes,
ner animals.
he Teleostei or osseous fishes the segmentation is also partial, but with a
approach to the unequal cleavage of the Amphibia.

. DEVELOPMENT OF THE OVUM IN GENERAL.

I. THE BLASTODERM.

m the preceding account of the segmentation of the ovum it ap-
that in the amniotic vertebrates the general result of that process is
rmation of a flattened or membranous plate or layer of organised
and the further observation of the progress of development of the
shows that the whole of the genetic changes to which the parts of
ture embryo owe their origin take place within, or in close connec-
ith the cellular elements of this plate or membrane. It is essentially
ore the germinal part of the egg, and in the discoid form which it
its in birds was appropriately named by Pander *germinal membrane*
haut) or Blastoderma, and this name is equally applied to the vesi-
form which it presents in mammals and some other animals.
the sauropsida, and to some extent also in the mammalia, the
derm, on the completion of the primary segmentation, does not
t of one layer of cells only, but shows a tendency to division into
ayers or two sets of cells, of which the external are generally
ore advanced in their state of development. From their relative
on these layers may be distinguished as the upper and lower,
ter and inner, primary layers of the blastoderm. Between
two layers, as they become more differentiated, at a subsequent
ill very early stage of blastodermic development a third or middle
makes its appearance, producing thus a trilaminar structure.
e result of all modern embryological research has shown that the
rigin and formation of the several systems, organs, and textures of
nbryo stand in definite relations to the several layers before men-
l or their derivatives, it will be apparent that the history of em-
ic development, more especially in its earlier stages, is in a great
re the narrative of the organogenetic changes occurring in the
, middle, and lower layers or cellular strata of the blastoderm.

Preliminary Notice of some of the Fundamental Phenomena evelopment.—Before proceeding to consider the somewhat intri-
nd still imperfectly understood subject of the nature and origin of
lastodermic layers, and their relation to the phenomena of develop-
it may assist in some degree the comprehension of what is to

part, remaining much thinner, forms the transparent
layer of the blastoderm extends over the whole of thi
layer in its primary condition reaches only as far as t
of the opaque area, becoming there continuous wit
substance of the yolk in the thickened part whic
germinal wall. After a few hours of incubation the
from being at first nearly circular, becomes oval and

Fig. 635. Fig. 6

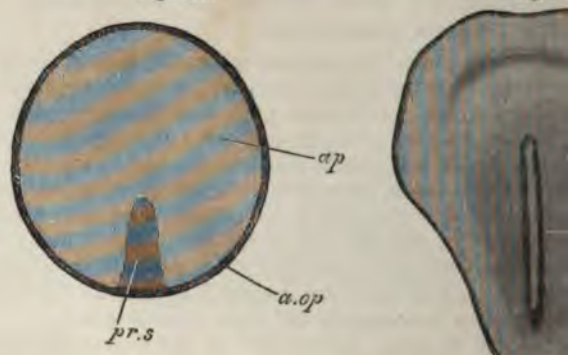


Fig. 635.—TRANSPARENT AREA OF THE BLASTODERM OF A CHICK AT A
SHOWING THE COMMENCEMENT OF THE PRIMITIVE STREAK. (F
pr.s, primitive streak ; *a.p*, area pellucida ; *a.op*, area opaca.

Fig. 636.—PYRIFORM TRANSPARENT AREA OF THE CHICK'S BLASTODERM
GROOVE. (From Balfour.)

pr, primitive streak and groove; *af*, amniotic fold commencing ;
round the primitive streak indicates the extension of mesoblast.

and on that side of the oval which afterwards become
of the pyriform space, and therefore near the margin
opacity appears (Kupffer, No. 113), which is grad
into the middle of the area and even beyond it and

groove into two ridges, extending backwards so as to enclose partially the front of the primitive streak; they unite or run into one at the forepart. These ridges and the thickened plates within them are the *dorsal ridges* and *medullary plates* which form the commencement of the brain and spinal marrow or cerebro-spinal axis of the embryo. It will afterwards be shown that the primitive streak and groove are comparatively evanescent and unimportant structures as regards the organs of the future embryo.

The dorsal ridges and medullary plates, continuing to grow steadily, extend themselves from before backwards, so as to encroach more and

Fig. 637.

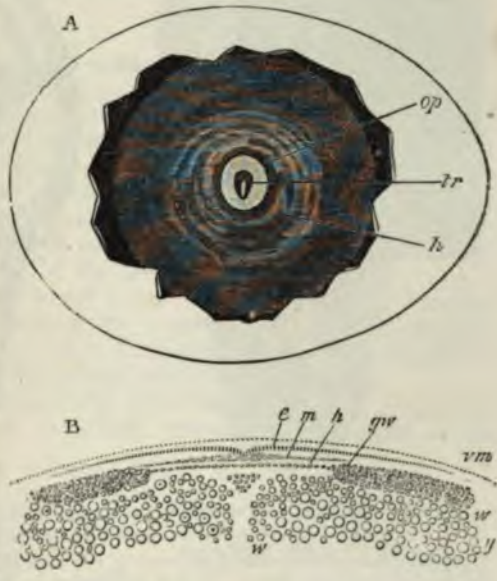


Fig. 637. — Surface view and diagrammatic section showing the relation of the primitive streak and blastoderm to the yolk in a fowl's egg after twelve hours of Incubation. (A. T.)

A, surface view, natural size; *op*, opaque area; *tr*, transparent area, pyriform, and showing the primitive streak in its narrower portion; *h*, haloes of the yolk surrounding the germinal disc; B, section across the disc, and a part of the yolk in the region of the primitive streak, magnified about ten diameters; *vm*, vitelline membrane indicated by a dotted line; *e*, the epiblast in the region of the primitive streak, showing the depression in the middle of the upper surface formed by the primitive groove; *m*, the mesoblast beginning to be formed, and spreading outwards from the epiblast at the primitive streak; *h*, the hypoblast, extending across below and passing at the sides into the germinal wall of the yolk, *gw*; *w*, the white; and *y*, the yellow or granular yolk substance.

more upon the primitive streak, which they, along with the mesoblastic columns on either side of them, partly extrude and partly enclose; and the ridges, rising and approaching one another, unite together along the dorsal line, first at a limited space and then more completely till at last they form a closed medullary tube, wider anteriorly in its cephalic part, the whole thus giving rise to the primitive form of the brain and spinal marrow.

Below the medullary tube there is formed about the same time the cellular column named *chorda dorsalis* or notochord, which occupies the place of the centres of the future bodies of the vertebræ and basis of the cranium, and by a somewhat later process the rudiments of the vertebræ themselves in their centra or bodies, which enclose the notochord, and their neural arches which surround the medullary canal, together with the muscular plates, which are the source of the voluntary muscles, come to be developed from the middle layer.

The formation of blood-vessels and blood and the simultaneo
lopment of the heart follow in another part of this layer, and in
what later stage there take place the inflection and other change
whole blastodermic layers which mould the body of the embry
semblance of its later form, give the distinction of head, trunk, a
and lay the foundation of the alimentary canal, its accompanying g

Fig. 638.

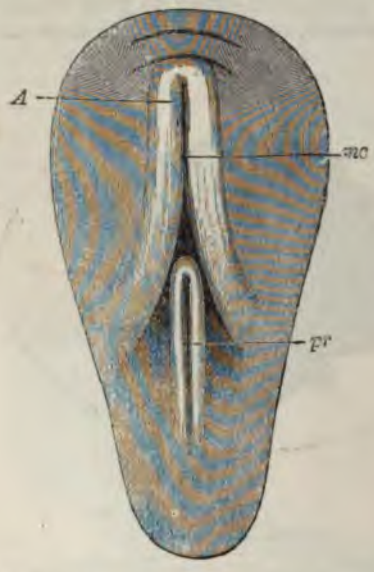


Fig. 639.

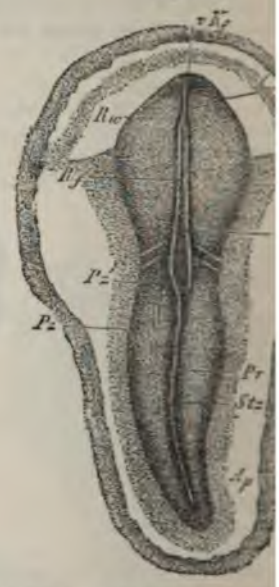


Fig. 638.—Surface view of the transparent area of a blastoderm of somewhat diagrammatic (from Balfour.)

pr, primitive groove, closed in front by the coalescence of the two lat
mc, medullary groove, having on each side the medullary folds or ridges A
meet in front to enclose the groove, but diverge behind so as to enclose t
streak ; in front the fold of the amnion is commencing.

Fig. 639.—Area pellucida and rudiments of the embryo-chick of day. ♀ (From Kölliker.)

pr. primitive streak and groove ; *Rw*, dorsal or medullary ridges meeting i
medullary groove near its middle ; *stz*, axial zone ; *Pz*, parietal zone ; *Pz*^{1}, t
somites ; *Ch*, notochord ; *Vkf*, cephalic fold ; *vD*, anterior intestinal fold shin
vAf, anterior or amniotic fold ; *Ap*, area pellucida.

and other organs, together with the extra-embryonic structur
the amnion, yolk-sack and allantois, constituting the coveri
embryo and membranes of the developed ovum.

2. **Relation of the Layers of the Blastoderm to the ment of Different Systems and Organs.**—In this comple
mental process, according to the views of Remak, with s
modification as is necessary to bring them into conformity with
of more recent discovery, the upper layer of the blastoderm,
name epiblast (or *neuro-epidermal*), is the exclusive source of th
the nervous system, central and peripheral, with the organs of

ring of the body and lining of the mouth, together with its ids and other parts. The lower layer or hypoblast (the *ular*) gives rise to the epithelial lining of the alimentary passages, the principal gland-ducts and the cellular ele- glands.

Fig. 640.

L VIEW OF A BLASTODERM AND EM- AVING FIVE MESOBLASTIC SOMITES

part of the primitive streak; *p.pr*, he medullary ridges have come to- ter part of their extent, but have he caudal swellings are visible on

ast undergoes subdivision and re complex destination. By n it forms the matrix of the al skeleton and the associated cles. By the upper plate of t (*Somatic or parietal Meso-* rise, in association with the e osseous, fibrous, muscular, ary substance of the body- s; while its lower plate (*visceral mesoblast*), separated er by the body-cavity, supplies the formative material and muscular wall of the alimentary canal, the lymph and system, and the urinary and generative organs.

risions or plates of the mesoblast now referred to (parietal mesoblast) in extending themselves peripherally in the

Fig. 641.

VERSE SECTION THROUGH THE K BEFORE AND SOME TIME AFTER OF THE MEDULLARY CANAL, TO WARD AND DOWNWARD INFLECTIONS ODERM (after Remak).

l of the first day. 1, notochord; l; 3, edge of the dorsal lamina; esoblast divided into upper and hypoblast; 7, section of proto-

l day in the lumbar region. 1, heath; 2, medullary canal now ion of the medullary substance l; 4, cuticular layer of epiblast; last; 5', visceral mesoblast (one the body cavity); 6, hypoblast estine and spreading over the natic wall going to form the visceral wall passing into the

rum, are more or less associated with the upper and lower per with the epiblast, the lower with the hypoblast, so as mposite sheets of the blastoderm, the upper of which we shall *etal or somatic wall*, and the lower the *visceral or splanchnic* natopleure and Splanchnopleure of Foster and Balfour, these the upper gives rise by its inflection to the amnion

or proper embryonic covering, which is continuous with the abdominal wall of the embryo at the umbilicus; while the lower sheet forms in its extension the greater part of two other membranes which are in direct continuity with the wall of the alimentary canal, viz., the yolk-sack and the allantois, all of which will be described later.

It requires to be noticed however that the foregoing account, though true of the great majority of mammalia, does not apply to them all. It has been long known, according to the discovery of Bischoff (No. 21, iv.), that in the guinea-pig the order of the position of the blastodermic layers is inverted in such a manner as to place the epiblast internally and the hypoblast externally, with a corresponding difference in the relative position of the parts developed from the several layers: and it has been recently shown by A. Fraser that a similar inversion of the layers exists in the rat and mouse. (Brit. Assoc. Aug. 1882.)

The existence of several laminæ in the germinal substratum was first suggested by C. F. Wolff in his celebrated work Theoria Generationis, published in 1759, and in his later Memoir on the Development of the Intestine first published in 1767 and republished in German by J. F. Meckel in 1812. It is, however, to the more exact researches of Pander, conducted under the direction of Döllinger of Würzburg, and published in 1817, and the modifications of them by Von Baer (1826-1837), that we owe the first consistent attempt to connect the development of the several organs and systems of the embryo with the different constituent parts or layers of the blastoderm. Pander recognised a trilaminar structure of the blastoderm and distinguished the three layers composing it, in their order from above downwards, or from without inwards in the egg, as the *serous*, *vascular*, and *mucous* layers (see Nos. 9, 10 and 12).

In 1850-54 a further important advance was made in the knowledge of the constitution of the blastodermic layers, by the discovery by Remak (No. 25) that the greater part of the middle layer soon after its formation comes to be divided into two laminæ, and separated by a space which corresponds to the perivisceral cavity—a fact which had been partially foreseen by Von Baer. So marked a division of the middle layer and distinction of the parts which are afterwards developed from its two laminæ, might seem almost to warrant the recognition of four distinct layers in the blastoderm; but it will be found on the whole more convenient to consider the fundamental layers as only three, to which, following the nomenclature of Foster and Balfour, we shall henceforth apply the designations of epiblast, mesoblast, and hypoblast, terms which are synonymous with those of ectoderm, mesoderm, and entoderm, employed by many authors.

3. **Origin and Constitution of the Blastodermic Layers**—Returning now to the consideration of the constitution of the blastoderm, we shall find some difference of opinion prevailing among embryologists on this subject, and more especially as to the mode of origin of the middle layer. We cannot enter into a full discussion of this question here, but we shall endeavour to present a very brief view of the results of the most recent researches regarding it.

In the class of birds, as already noticed, the discoid blastoderm presents from the first, or from a very early period of incubation, a bilaminar arrangement of its cells, and there is no difficulty in identifying the greater part of the upper and more advanced layer with that which is afterwards known as epiblast. The lower layer consists at first of larger, more scattered and loose granular cells, but these or a part of them soon assume the more definite form of a distinct layer of flattened cells occupying the lowest place and therefore corresponding, according to most embryologists, to that which is later known as hypoblast. As yet there is no appearance of mesoblast or middle layer; but between

eighth and twelfth hour of incubation in the fowl's egg, during
h time the primitive streak has been formed, the blastoderm under-
considerable change in connection with the development of the
lle layer. The primitive streak consists in fact of a linear or strap-like

Fig. 642.

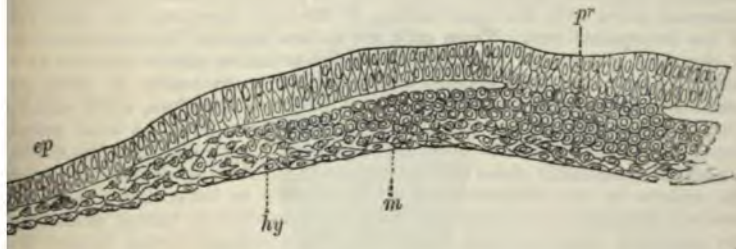
. 642.—MICROSCOPIC VIEW OF A VERTICAL SECTION THROUGH HALF THE BLASTODERM OF A NEWLY-LAID EGG. (From Stricker.) $\frac{250}{1}$

upper layer of small nucleated cells ; D, lower layer of larger granular cells ; M, segspherules lying in the subgerminal cavity ; A, substance of the white yolk below the

s of cells, formed by direct proliferation from the lower cells of the
last, and continuing to adhere to that layer along the whole length
he streak. This is the axial plate of His and Kölliker, and, as first
n by the latter observer, is undoubtedly the commencement of a
lle layer developed in connection with the epiblast.

t this time, that is, after the formation of the primitive streak and
ious to the appearance of the medullary plates and chorda dorsalis,
blastoderm in the forepart of the germinal area, both of birds and
mals, consists of only two layers, and it is not till some time later
the mesoblast which gives rise to the protovertebral plates is found
ave extended itself into this region.

Fig. 643.



343.—TRANSVERSE SECTION THROUGH THE FRONT END OF THE PRIMITIVE STREAK AND BLASTODERM OF THE CHICK. (From Balfour.)

primitive groove ; *m*, mesoblast ; *ep*, epiblast ; *hy*, hypoblast.

ith regard to the much debated question of the mode of origin and
nsion of the mesoblast two different views mainly prevail among the
yologists who have most recently investigated the subject ; according
e of which, maintained by Kölliker (Nos. 28 and 99), Braun (No. 110)
others, the mesoblast is entirely derived from the axial plate of the

Fig. 644.—LONGITUDINAL SECTION OF THE BLASTODERM OF THE PRIMITIVE STREAK AND THE PART IN FRONT OF IT (from

pr.s, primitive streak; *ep*, epiblast; *hy*, hypoblast in front o
n, nuclei in the yolk wall; *yk*, yolk.

In a recent revision of the whole evidence on this questio
Balfour and Deighton (No. 108), founding their opinion upon
observations made by them on the common fowl and duck
lateral expansion of the layer of mesoblast formed in connectio
there takes place both in the region of the primitive streak a
the germinal area a rapid proliferation of cells presenting a s
connected below with the upper surface of the lower layer o
of the transparent area. These cells are at first separate
of the axial mesoblastic plate, but below the primitive str
mately united with both epiblast and hypoblast as to re
continuous in that situation. Balfour and Deighton theref
with Kölliker the origin of a main sheet of mesoblast from
streak plate, are inclined to differ from him so far as to att
the lateral mesoblastic plates which form the mesoblastic so
the embryo to the differentiation of hypoblastic or lowe
however they allow are continuous with the wing-like or
the primitive streak or axial mesoblast. These authors fu
third set of mesoblastic elements may be derived from the p
the blastoderm, viz., from the nuclei and cells of the germi

holoblastic segmentation of the ovum, seems to determine some modification in the mode of formation of the layers. As already stated, the completion of the primary segmentation leads to the covering in of the whole ovum with a layer of flattened nucleated cells, within which,

Fig. 645. Fig. 646.

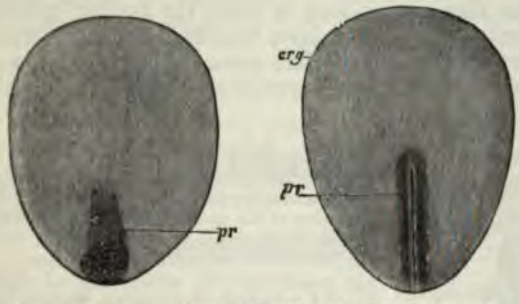


Fig. 645.—Embryonic area from the ovum of a rabbit of seven days. $\frac{30}{1}$. (From Kölliker.)

pr, first rudiment of the primitive streak.

Fig. 646.—Embryonic area from the ovum of a rabbit of eight days. $\frac{30}{1}$. (From Kölliker.)

arg, border of the embryonic area; *pr*, primitive streak with groove.

Besides the fluid remains of the original yolk-substance, there is the inner mass of granular cells or segmental spheres, which by their further development and extension come to produce one or more deep or internal layers, which gradually spreading over the interior give a bilaminar or trilaminar structure to an increasing area of the blastoderm.

Fig. 647.

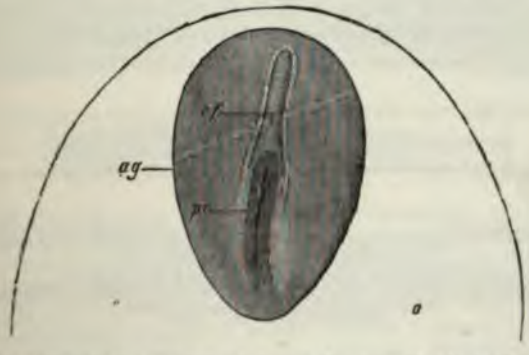


Fig. 647.—Embryonic area, with outline of part of the vascular area, from a rabbit's ovum of seven days $\frac{30}{1}$. (From Kölliker.)

oo, vascular area; *ag*, embryonic area; *pr*, primitive streak and groove; *rf*, medullary groove.

It is in the central part of the blastoderm, at the fifth day in the rabbit, and when the inner layer has advanced over about half of the interior, that a discoid thickening or opacity occurs which gives rise to

the *embryonal area* (*tache embryonnaire* of Coste); and it is now tained by the observations of Hensen, Kölliker and others, that th appearance of the primitive streak and its groove and the commenc of the medullary canal and vertebral rudiments take place in a n essentially the same as in birds. But the same or even a greater of doubt exists in mammals as in birds as to the mode of origin mesoblast, and there arises also in them the further question, v how far the external vesicular layer of cells corresponds precisely later epiblast, as was for some time generally believed to be the c whether the deeper or internal layer of cells may also contribute formation of that layer.

Fig. 648.

Fig. 648.—Embryo of the dog seen from abo a portion of the blastoderm attache

The medullary canal is not yet closed, but s dilatation at the cephalic extremity with a partial into the three primary cerebral vesicles; the post tremity shows a rhomboidal enlargement. The fold crosses below the middle cerebral vesicle. mordial vertebral divisions are visible; *so*, th division of the blastoderm; *sp*, the lower divisio they have been cut away from the peripheral par

Some part of the difficulty now mentio arisen from the observations of A. Rauber (2 who in 1875 detected the presence, in additio other layers of the blastoderm in the rabbit, layer of flat cells closely adherent to the outer which he found to have only a temporary e and gradually to disappear in the course of velopment of the other layers. Lieberkühn years later (No. 104) showed that the outer flat cells described by Rauber, which form th of the outer covering of the blastodermic resulting from the primary segmentation, is principal source of the permanent epiblast, but that that layer as wel hypoblast or lower layer are the product of differentiation of the cell form the internal mass of segmentation spheres or "yolk-rest."

Fig. 649.

Fig. 649.—Two transverse sections through the embryonic area of th of seven days. (From Balfour.)

A, through the anterior part of the embryonic area for about half its bre through the posterior part of the primitive streak; *ep*, epiblast; *Ay*, hypoblast.

Kölliker, who was led by earlier observations on the blastodermic v the rabbit to coincide with the views of Rauber as to the transitory natu outer layer of flat cells, has more recently (1882) (No. 99, ii.) revie

whole subject and has described the result of renewed observations made on the rabbit as follows :—

The embryonal area of the rabbit's blastodermic vesicle consists at the fifth day of three layers, of which the upper, corresponding to Rauber's flat cells, is the same with the outer layer of the primitive blastodermic vesicle, while the other two layers arise by the widening out of the mass of inner cells, and its subsequent division into two laminæ. The outer layer of cells is transitory, and is not the source of the permanent epiblast, which is formed, as Rauber supposed, from the upper of the two internal layers of cells, while the lower of these gives rise to the hypoblast. After the disappearance of Rauber's cells the blastoderm becomes for a time distinctly bilaminar, the cells of the upper layer being more regularly set

Fig. 650.

Fig. 650.—A SECTION THROUGH PART OF A BILAMINAR BLASTODERM OF THE CAT. (E. A. S.)

ect., *ent.*, ectoderm, entoderm ; *z.p.*, thinned out zona pellucida.

and columnar in form ; those of the lower being large and flat, as well described by Hensen (98) and Schäfer (No. 100).

The mesoblast first makes its appearance in the course of the seventh day in connection with the formation of the primitive streak, and according to Kölliker is formed entirely by proliferation of cells belonging to the epiblastic layer. This cellular multiplication takes place in an axial plate very similar to that previously described in the bird's egg, and the mesoblastic sheet which results extends in the

Fig. 651.

Fig. 651.—SECTION OF TRILAMINAR BLASTODERM OF THE RABBIT OF EIGHT DAYS AND NINE HOURS. (Kölliker.)

ect., *ent.*, as before; *mes.*, mesoderm continuous in middle (*pr.*) with ectoderm.

same manner forward along with the primitive streak from the margin of the embryonal area where their development begins.

According to Kölliker the cells of the mesoblast have from a very early period of their existence a marked spindle and stellate character, and in this respect differ obviously from those of the epiblast and hypoblast ; and thus the sheet of new formation is easily recognisable both on surface views and in sections, as it expands from its median attachment to the axial plate laterally over the surface of the germinal area. The sheet of mesoblast spreads out at first only to the sides of the primitive streak and backwards, being widest behind ; but after a time it also extends forwards in the form of two lateral plates which spread into the anterior part of the germinal area, in which previously the blastoderm was only bilaminar, and finally it passes from the embryonic area into the whole extent of the surrounding vascular area.

The observations of Heape, made like those of Lieberkühn upon the blastoderm of the mole, confirm those of Kölliker upon the rabbit in so far that

they show the larger portion of the mesoblast to be produced from epibla
axial plate of the primitive streak; but he is led by his researches also
cate the view that a portion of the mesoblast is derived from hypoblas
anterior region of the embryonal area in the same manner as Balfour ho
the case in birds. He is also inclined to believe that the flat cells of
combine in part with, or are converted into, the upper layer of the p
internal cells to form the epiblast (No. 107).

Fig. 652.

Fig. 652.—Section of the rabbit's blastoderm at six days. (From Van Beneden.)

ect., upper layer, or Rauber's cells; *mes.*, middle layer; *ent.*, lower

E. Van Beneden takes quite a different view of these phenomena (
Not admitting the transitory nature of the upper layer as described by R
holds that this layer, which is co-extensive with the whole blastodermi
becomes the epiblast, that from the more restricted plate of dee
there is first formed a primitive lower layer, and that subsequently th
place a separation or differentiation of this into a smaller central inte
plate of rounded mesoblastic cells and a wider lower layer of flat hy
cells (see fig. 652).

Fig. 653.

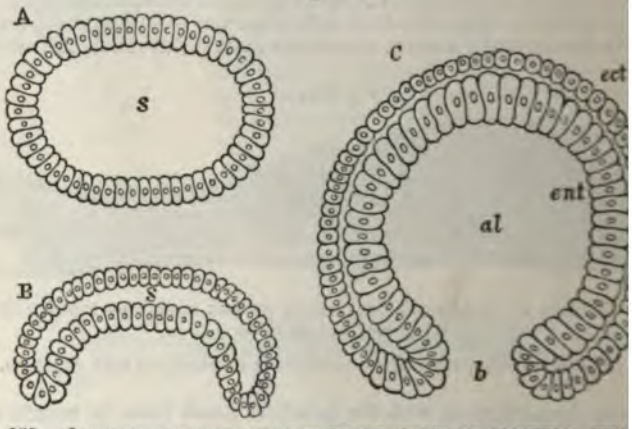


Fig. 653.—Ovum of amphioxus in the three stages of blastula, inva and gastrula. (From Haeckel, after Kowalevsky.)

A. blastula stage, or single vesicular layer of cells resulting from segmentati
vagination stage forming two layers; C, gastrula stage in which a primitive
cavity is enclosed by a bilaminar blastoderm; *s*, segmentation cavity; *ect.*, e
ent., inner layer; *al.*, primitive alimentary cavity formed by invagination; *b*,

GENERAL RELATIONS OF THE BLASTODERM TO THE OV

Invagination of the Blastoderm, Gastræa Theory.—The brilliant
by Kowalevsky in 1867 (No. 83) of the production of a bilaminar condit
blastoderm in Amphioxus and some invertebrate animals, by the infold
vagination of a primary simple cellular blastodermic membrane (blastula)

nary segmentation, and the attempt of Haeckel (No. 89) which fol-
w that a somewhat analogous process is universal throughout all
hich the distinction between ectoderm and entoderm exists, gave rise
new mode of viewing the relation of the blastoderm to the ovum and
development. In the Amphioxus the invagination consists in the
k or inwards of one half of the primary blastodermic vesicle upon
that the two at last come into contact, by the gradual disappearance
vening cavity. At the same time the double wall thus produced
and converges at the margin of reduplication so as to enclose a new
communicates with the exterior by a narrow aperture; this con-
gastrula form of the developing ovum and embryo. The two
g the wall of this gastrula correspond with ectoderm and entoderm
y outer and inner layers of the blastoderm, and the now contracted
ıvagination receives the name of blastopore appropriately given to
kester (No. 44). Now although it is very apparent that in the higher
s well as in many of the lower animals, there is no actual infolding
ion of the blastoderm such as that now described, yet there are
s connected with the origin of the layers, and their continuity at
ıere the first traces of the embryo appear, which seem to make it
efer the phenomena of blastodermic and early embryonic develop-
ıeral principle in some degree consistent with the invagination and
ies of Kowalevsky and Haeckel.

in this place enter upon the consideration of this extensive and
ct; but it may be proper to refer briefly to one or two points in
ith its history in the higher vertebrates as bearing upon these
ews.

e and Neurenteric Canal.—We have had occasion more than once
e existence of the blastopore aperture or indications of it in the
rates. The more trustworthy of these indications are to be found
e primitive streak and its groove, and in certain depressions and
ugh the layers of the blastoderm which have been detected in their
s more immediately in the space between the hinder extremity of the
l primitive medullary canal and the fore part of the primitive streak
and reptiles the deepest aperture has been observed, in the form
rd passage, which comes to be established some time after the forma-
mesoblast and protovertebral somites, and which leads from the
rom the hinder part of the still open medullary canal into the
or primitive alimentary cavity round the hinder extremity of the
ıd to which the name of *neurenteric canal* is given. The fact that
lopment of a primitive trace takes place in all vertebrated animals
ı, and not, as was formerly held, for the higher tribes, in the centre
inal area, affords some explanation of the very obscure relation
tween the outer and inner primary layers of the blastoderm, and
way for the application of the theory of invagination to the early
f development in the amniota as well as in the lower vertebrates.

uring to explain this matter we cannot do better than follow closely
sition of the subject given by Balfour, whose own researches have
demonstrate the applicability of the theory of invagination to the
ıment of the higher vertebrates. A careful consideration of the
the primitive trace and its groove to the ovum and earliest
of development, its transitory existence as discovered by Dursy in
, the occasional perforation of the layers of the blastoderm in a
d its intimate connection with the origin of the mesoblast, has led
after him several other embryologists, to the view that the primitive
estige of a blastopore or aperture of invagination of the blastoderm.
groove and prolongation as a trace arise from the very early and
on of the blastoderm round these structures.

ion of this subject we may refer to the diagram contrived by Balfour,
elations between the medullary groove, the primitive trace, and the
lastoderm in three different forms of development as presented by
, the *Elasmobranchs*, and the Amniota.

We shall suppose that in all the three sets of animals here referred to, the primitive blastoderm already consists of two layers or groups of cells, viz., an external epiblastic, and a deeper or internal set representing the primitive hypoblast, and (leaving in the meantime the mesoblast out of view) supposing further that the outer layer or epiblast has to a greater or less extent covered in the deeper layer, there is seen in A, which represents the frog's ovum, a round spot, *yk*, where the inner larger cells or yolk spheres are still exposed, and at *ne* a depression where the outer and inner cells are continuous. These together represent the blastopore or place of invagination; and it will be seen further that it is at this point and from it forwards, that is towards the head end of the embryo,

Fig. 654.

Fig. 654.—DIAGRAMS ILLUSTRATING THE POSITION OF THE BLASTOPORE, AND THE RELATION OF THE EMBRYO TO THE YOLK IN VARIOUS MEROBLASTIC VERTEBRATE OVA. (From Balfour.)

A, type of the Frog; B, elasmobranch type; C, amniotic vertebrate; *mg*, medullary plates and groove; *ne*, neurenteric canal; *bl*, portion of blastopore adjoining this canal; *yk*, part of yolk not yet enclosed by the blastoderm; in B and C, *bl* is the seat of the primitive streak.

that the medullary canal, *mg*, is developed. By the extension of the outer layer the round spot, long known as the anus of Rusconi, is covered gradually over by the epiblast, and the aperture of invagination reduced in size, is finally closed; the neurenteric canal being left, however, for a time more deeply. The permanent anus is of later formation.

In the elasmobranch fishes (B), of which the ovum is meroblastic, the blastoderm is seen to have extended only a certain way over the yolk, but in such a manner as to involve or surround the blastopore aperture, which may be supposed to have been previously marginal or at the union of the outer and inner blastodermic layers, and thus to give rise to a prolongation of the aperture in the form of a groove, *bl*, by the meeting of the blastoderm from the two sides.

In the amniota, C, the separation of the embryonic area still further from the margin of the blastoderm is effected by the rapid extension of the latter beyond

the aperture of invagination, and thus the blastopore and its prolongation as a primitive trace and groove are brought more fully within the embryonic area, while the medullary groove stands in the same relation as in the lower animals. It will be seen, however, that the first indication of the primitive trace even in the amniota arises marginally, and it is probable therefore that it essentially corresponds in position with that of the lower vertebrates.

From this it appears that the first traces of embryonic formation in these several groups of animals stand in a constant and determinate relation to the blastopore, or if we do not go so far as to admit the occurrence of actual invagination, to the place of continuity between the upper and lower primary layers of the blastoderm, and to the seat of primary differentiation of the principal part of the mesoblast.

Fig. 655.

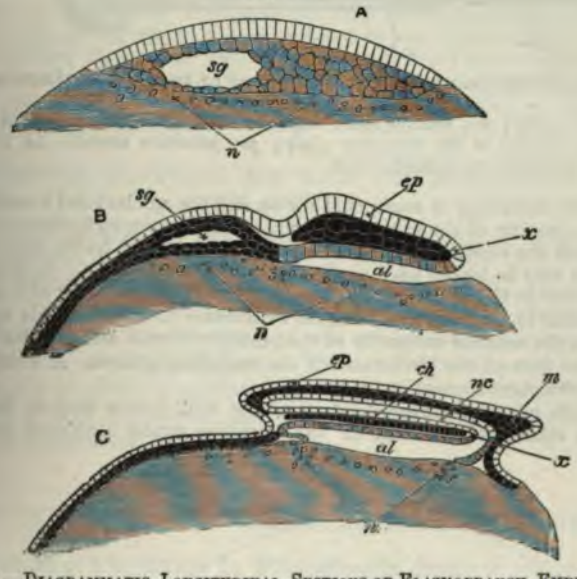


Fig. 655.—Diagrammatic Longitudinal Sections of Elasmobranch Embryo and Blastoderm. (From Balfour.)

A, younger stage with two primary layers; B, more advanced stage with three layers and invagination at the hinder end of the embryo; C, still more advanced; the embryo raised from the blastoderm with neural and primitive alimentary canals and neurenteric communication between them.

ep, epiblast; *m*, mesoblast; *x*, epiblast continuous with hypoblast; *nc*, neural canal; *ch*, notochord; *al*, alimentary cavity; *sg*, segmentation cavity; *n*, nuclei of the yolk.

It may be proper to make mention here of the remarkable observation by E. Van Beneden of the existence of a small aperture or deficiency in the external layer of cells on that side of the rabbit's ovum where the inner cells or segmental spheres (forming the yolk-rest) adhere to the outer, which appeared to him to have the effect of establishing continuity between the outer and inner layers of the blastoderm in the manner of a blastopore. But there are difficulties in the way of reconciling this view of a mammiferous blastopore with those of Balfour and others on this subject as founded on the observation of invagination in the lower vertebrates. (See No. 75.)

The existence of a neurenteric canal or blastopore in birds was discovered by Gasser in 1879 (No. 103), and has been confirmed by Balfour and Braun; and from these observations it appears that it is subject to some variation in position and extent in that class of animals.

This discovery was extended to the class of Reptiles (Lizards) by Kupffer and Benecke in 1879 (No. 112), and confirmed by original observations by Balfour; and a further series of researches by Kupffer (No. 113) in the present year, have shown that the neurenteric canal exists in Ophidia and Chelonia.

We owe to Hensen the first clear account of the development of the primitive streak in mammals (rabbit), and his observations have been ably followed up by Kölliker. The observations of Schäfer on the early blastoderm of the guinea-pig have shown more clearly the connection subsisting between the lower

Fig. 656.

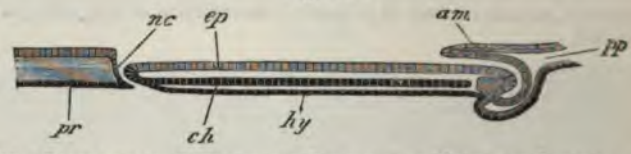


Fig. 656.—Diagrammatic Longitudinal Section of an Embryo of Lacerta. (From Balfour.)

pp, body cavity; *am*, amnion fold; *nc*, neurenteric canal; *ch*, notochord; *hy*, hypoblast; *ep*, epiblast of the medullary plate; *pr*, primitive streak. In the primitive streak all the layers are partially fused.

layer in the medullary or embryonic region and the epiblast and mesoblast in the anterior extremity of the primitive streak, and according to Balfour a comparison of this with the conditions observed in reptiles and birds leaves little doubt that this union may be looked upon as the dorsal lip of a blastopore. In the mole (and partially also in the rabbit) Heape has ascertained the existence of a neurenteric canal similar to that observed in other vertebrates (No. 107). This appears first as a pit at the anterior extremity of the primitive streak, and in later stages perforates the floor of the hinder end of the medullary groove. A. Fraser also has seen the neurenteric canal in the rat.

Direction of the Embryonic Axis.—It is well known that in the common fowl and other birds the line of the primitive streak continued through the

Fig. 657.

Fig. 657.—Outlines showing the relation of the axis of the embryo to the ovum in birds and mammals. (A.T.)

A, Fowl's egg opened after 35 hours' incubation, showing the embryo chick within the transparent and vascular area on the surface of the yolk; at right angles to the long axis of the egg; B & C, two early stages of development in the ovum of the dog, showing the primitive streak (in B) and the commencing embryo (in C); the line of the uterine tube and long diameter of the ovum being at right angles to the vertebral axis of the embryo.

medullary groove which represents the vertebral axis of the embryo is during the first two days of incubation always placed at right angles to the long axis of the egg, and in a determinate position, so that if one looks down upon the germinal area in an incubated egg the small end of which is placed towards the right hand, the cephalic extremity of the embryo is directed forwards, and the caudal extremity and primitive streak backwards.

There is some reason to believe that the line of the first cleavage of the germinal area may be the same with that of the first embryonic axis as now described both in birds and amphibia, but this is not fully known. It deserves to be noted, however, that the position of the cicatricula in the yolk or ovarian egg is also fixed, being invariably close to the pedicle of the ovicapsule, and all this seems to indicate some constant relation between the position of the egg, the mode of cleavage, and the attitude of the first lineaments of the embryo.

In mammals also numerous observations show that the axial line of the embryo is constant, and is placed so as to cross the long axis of the uterus, as may be seen in the dog, pig, sheep, rabbit, rat and guinea-pig. But in both mammals and birds this first determinate position is soon lost, and a more variable one is assumed by the embryo when its development has advanced so as to separate the body from the rest of the blastoderm by an umbilical constriction. The cause of these relations of position is still entirely unknown.

III. SPECIAL HISTORY OF THE DEVELOPMENT OF THE OVUM.

In the ova of the higher vertebrates the phenomena of development fall naturally into two groups, according as—1st, they occur in parts belonging strictly to the body of the future embryo, and are therefore embryonic ; or 2nd, they are connected with the production of parts which being situated external to the body of the embryo may be regarded as accessory and called extraembryonic. We shall begin with the second of these divisions as affording a convenient opportunity of explaining some general relations of connection between the embryo and the other parts of the developing ovum.

I. DEVELOPMENT OF EXTRAEMBRYONIC PARTS.

Membranes of the Ovum in General.—In the three higher classes of vertebrates the extraembryonic structures consist of the membranes named yolk-sac, amnion and allantois ; and to these may be added a fourth, existing only in mammals, and which may best be named the chorion. We shall first state the most general facts as to the development of the membranes ; and then in connection with human utero-gestation describe the formation of the placenta, which is the organic medium of connection between the ovum with its embryo and the maternal uterus.

It is to be noted that this description will not apply to many of the phenomena observed in the exceptional forms in the guinea-pig, rat and mouse.

The Yolk-sac.—This name is given to an organised and vascular covering formed by the extension of the layers of the blastoderm over the surface of the yolk, and existing in all vertebrate animals.

The yolk-sac is the seat of the first circulation of the blood in the vitelline or omphalo-mesenteric vessels of its vascular area, and in oviparous animals especially these vessels spread at a later period over the whole surface of the yolk in the membrane which forms the sac. In birds the food-material of the yolk is absorbed by these vessels and

conveyed by them as nourishment into the system of the embryo, through a special structural arrangement of the membrane, which is thrown into folds and beset with tufted groups of cells surrounding the vessels of its interior. (Courty, in Ann. d. Sc. Nat. 1844.)

In mammals as in birds the vascular area spreads over the surface of the yolk, but does not in all cover it entirely. In some the yolk-sac grows with the embryo and other parts of the ovum to a large proportional size, which it retains up to an advanced stage of development, while in others its growth ceases at an early period, and this is followed in some by the atrophy and complete disappearance of the yolk. The cavity of the yolk-sac is in most occupied chiefly by a coagulable fluid without the peculiar yolk corpuscles which belong to the yolk-substance of birds and reptiles.

The differences which are observed in the extent of development of

Fig. 658.

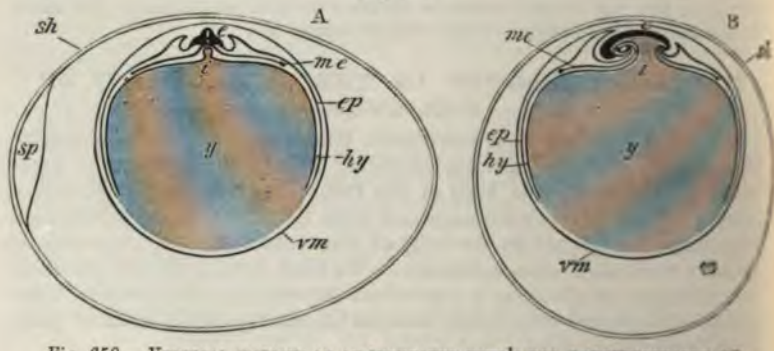


Fig. 658.—VERTICAL SECTIONS OF AN INCUBATED FOWL'S EGG, LONGITUDINALLY AND TRANSVERSELY, AT THE THIRD DAY.

The figure is diagrammatic and is intended to show the early relations of the membranes to the embryo and rest of the egg. The parts of the embryo and those near it are represented as proportionally larger than natural. A, longitudinally in the egg, and across the embryo; B, across the egg and longitudinally in the embryo; *sh*, shell and external covering of the egg; *sp*, air space at the larger end; *y*, the yolk partially covered by the spreading layers of the blastoderm, viz., *ep*, epiblast, *hy*, hypoblast, and *me*, visceral mesoblast as far as the vascular area extends; *vm*, vitelline membrane; *w*, space occupied by the albumen of the egg; *c*, the embryo (shaded dark) consisting of its medullary and protovertebral axis, and partially surrounded by the commencing folds of the amnion in connection with epiblast (*ep*); *i*, the place of communication of the primitive intestine with the yolk-sac. For the sake of clearness the parietal mesoblast has been omitted.

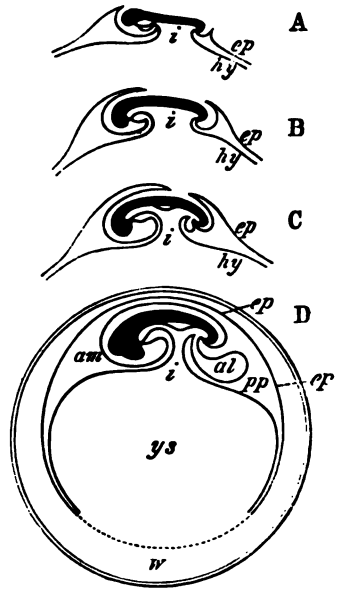
the yolk-sac and its blood-vessels may be traced to differences in their relation to the chorion in utero-gestation. In rodentia, and to some extent also in insectivora and cheiroptera, it comes into contact or union with the non-placental part of the chorion, and furnishes blood-vessels to that membrane. In ruminants it is very soon drawn out into two attenuated tubes which extend towards the ends of the greatly-elongated ovum. In carnivora it is of considerable size, stretching through the ovum towards its opposite poles, but without vascular union with the chorion.

In the human species the yolk-sac, which is also named the umbilical vesicle, retains its vascularity for a short time, and continues to grow up to the fifth or sixth week, at which time it has assumed a pyriform shape, and is connected by a tubular vitelline duct with the intestine.

ovum of from five to six weeks it is about a quarter of
ch in diameter, and lies loosely in the space between the amnion
chorion. At a later period, the duct elongating with the umbilical
the vesicle remains flattened and atrophied in the same relation to
membranes as before. In the third month its duct is found con-
with a coil of intestine which in the form of a hernia occupies
umbilical cord outside the abdomen of the embryo (see fig. 789,
). At a later period the much elongated and attenuated duct
the vitelline vessels, now shrunk and impervious, may still be traced
gh the umbilical cord, while the flattened vesicle may be found even
the end of the term of uterogestation.

Amnion.—This vesicular covering of the embryo does not exist
phibia or fishes, but is present in all reptiles, birds, and mammals,

Fig. 659.



9.—DIAGRAMMATIC OUTLINES OF LONGITUDINAL SECTIONS OF THE EMBRYO-CHICK AT SUCCESSIVE PERIODS DURING THE FORMATION OF THE MEMBRANES. T.)

the beginning, B, towards the end
econd day of incubation; C, on the
ay; D, on the fourth day, showing
section of the whole egg. In
ome figures the embryo and the
curing inflections of the membranes
presented proportionally larger than
. The dark-shaded part indicates
mbryo: *ep*, epiblast; *hy*, hypoblast;
he sake of clearness the mesoblastic
ccompanying these are not represented).
the cephalic fold of the amnion has
; in B, it has increased, and the caudal
s commenced; in C, the two folds ap-
one another, leaving the amnion still
dorsally; in D, the outer fold or false
n has separated from the inner or true
which is now complete; *ys*, the cavity
yolk being gradually surrounded by the
ac formed of all the three layers of the
derm, and communicating at *i*, with
imentary canal; *al*, in D, shows the
ia beginning to expand from the in-
; in C, it is just beginning to appear.

h are hence named *Amniota*. It begins to be formed at an early
of development, and subsequently becomes distended by a fluid in
h the embryo floats and is attached by means of the umbilical cord
amniotic enclosure.

ie structure and mode of formation of the amnion are essentially
ar in the three classes of animals in which it exists. It generally
sts of two layers, derived respectively, the inner from the epiblast,
the outer from the parietal layer of the mesoblast; the first formed
stinct nucleated cells, the second presenting in later stages a fibrous
ture. The external layer possesses considerable muscular contractility
n some animals is partially vascular.

e formation of the amnion takes place by the gradual inflection in
sal direction from the flat part of the blastoderm adjoining the
yo of the two layers before mentioned, first at the cephalic, and

somewhat later at the caudal extremity and at the sides (see fig. 659, A, B, C and D), so that the two layers of which the amnion is composed are lifted up and separated from the remaining two lower layers (visceral mesoblast and hypoblast) of the blastoderm, by a space which is a peripheral extension of the pleuro-peritoneal cavity. The embryo thus comes to sink into a hollow produced by the rising of the amniotic folds round it. The backward folds deepening more and more, gradually converge on the dorsum of the embryo, and at last come together, the margins of the reflection narrowing rapidly and being finally completely obliterated or lost by their convergence and by the subsequent dissociation of the inner from the outer divisions of the folds (fig. 659, D). The separated inner division now becomes the entire closed sac of the amnion, connected only with the rest of the parts at the umbilical constriction where it is continuous with the integument of the embryo. The outer dissociated division is the *false amnion* of Pander and Von Baer, passing out into the peripheral part of the blastoderm, and constituting for a time an external covering of the ovum, which in birds and reptiles appears afterwards to be lost by thinning or absorption ; but which in mammals is probably connected with the development of the permanent chorion in a manner to be referred to hereafter.

In birds at a more advanced stage of incubation the true or enclosed amnion is surrounded externally by the expanded allantois. In mammals its relations vary somewhat according to the nature and extent of the proportional development of the yolk-sac and allantois. In the advanced stage of the development of the human ovum the amnion is to a great extent in contact with the interior of the chorion ; but its origin and formation do not differ materially from those of animals.

In the human embryo, as in that of most animals, the amnion is at first and for some time after its completion very close to the surface of the body, but after a time, corresponding to the fourth day of incubation in the chick and the fourth or fifth week of gestation in man, the increased accumulation of fluid within the amnion expands the membrane rapidly so as to remove it to a considerable distance from the embryo.

The muscular contractility of the amnion doubtless resides in its outer layer derived from the parietal mesoblast. The contractions appear to be rhythmic, and they may be seen in the opened incubated egg of the fowl, or even in the entire egg, by means of a bright light in a dark chamber, from the sixth or seventh day of incubation ; and it is probable that they are of a similar nature in mammals.

The human amniotic fluid contains about 1 per cent. of solid matter, consisting chiefly of albumen, with traces of urea, which is probably derived from the urinary secretion of the fœtus.

It would appear that there is a difference in the structure of the reflected or false amnion in birds and in mammals. In the former it is composed of the same two layers as the amnion itself, their position being reversed, but in mammals the development of the mesoblast appears to cease at the place of reflection of the true into the false amnion, so that the latter consists only of the epiblast.

The Allantois.—This membrane, sometimes also called urinary vesicle, exists as a fœtal structure in all the amniota, but not in fishes or amphibia ; and yet in the latter animals a corresponding vesicle is developed in the adult. In reptiles, birds, and mammals it originates at a very early period as a diverticulum from the hinder part of the primitive

intestine, but there are great differences in the degree and rate of its extension, a rapid and wide expansion occurring in some, while in others it remains of comparatively small size. It is the seat of an extended distribution of ramified and capillary blood-vessels which perform important functions in connection with the nutrition of the embryo and the aëration of its blood.

The allantois at its origin consists essentially of a thickened bulging portion of the visceral mesoblast, and a corresponding extension of the intestinal hypoblast within; and from recent researches in reptiles (Kupffer No. 113) would appear to have close relations with the neurenteric canal. The capillary network of commencing blood-vessels makes its appearance in its mesoblastic layer at a very early stage, and these become connected with the main vessels of the embryo by means of two

Fig. 660.

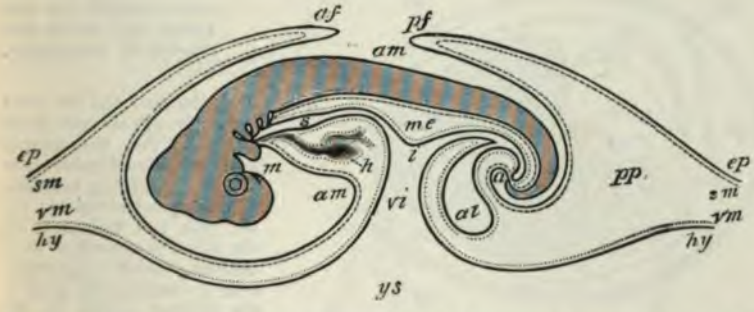


Fig. 660.—Enlarged diagrammatic outline of a longitudinal vertical section of the chick and neighbouring parts of the blastoderm on the fourth day. (A. T.)

ep, epiblast; *sm*, parietal mesoblast, together forming the *somatic plate*; *hy*, hypoblast; *vm*, visceral mesoblast, together forming the *visceral plate*; *af*, cephalic fold; *pf*, caudal fold of the amnion; *am*, cavity of the true amnion; *ys*, yolk-sac, leading by *vi*, the vitello-intestinal aperture to *i*, the intestine; *s*, the stomach and gullet; *a*, the future anus still closed; *m*, the buccal cavity or mouth formed in epiblast and still closed from the pharynx at the fauces, which are not shown; *me*, the mesentery; *al*, the allantoid vesicle communicating by its pedicle with the hinder intestine; *pp*, the space between the outer and inner folds of the amnion, which is an extension of the body cavity or pleuro-peritoneal space within the embryo between the parietal and visceral mesoblasts. The shaded part of the figure represents the head and trunk of the embryo in which the eye and the jaws with the branchial bars and clefts are indicated. The epiblast and hypoblast are drawn with entire lines, the parietal mesoblast with an interrupted and the visceral mesoblast with a dotted line.

arteries and two veins. The allantoic arteries are at first separate branches of the two primary divisions of the abdominal aorta, and subsequently, when the two aortas coalesce, they are derived from the hypogastric arteries, and have been called umbilical. The two returning vessels or allantoic veins pass into connection with the principal veins of the yolk-sac, and with them form the umbilical veins. The name of allantoic suggested by Balfour is preferable to that of umbilical for the vessels of the allantois.

The allantoid diverticulum soon takes the form of a flask-like vesicle, connected with the intestine by a narrow pedicle, as may be well seen in the chick on the fourth day, and in the embryo of the rabbit

or dog at a corresponding period. In all birds, as also in reptiles, it undergoes rapid dilatation and extension, and its inner hypoblastic portion being filled with fluid, and the doubled membrane flattening out in the space which intervenes between the parietal and visceral mesoblast, as far as is allowed by the separation of these two layers, viz., to the margin of the vascular area of the yolk, it follows the gradual extension of that area over the surface of the yolk; and finally, as the albumen gives place by its absorption into the yolk cavity, the allantois comes to occupy more and more of the intermesoblastic interval, and to fill the whole space between the amnion and yolk-sac on the one hand and the lining membrane of the egg shell on the other.

The allantoic blood-vessels are distributed both in its internal and external folds, but form a richer network on the latter, and there they

Fig. 661.

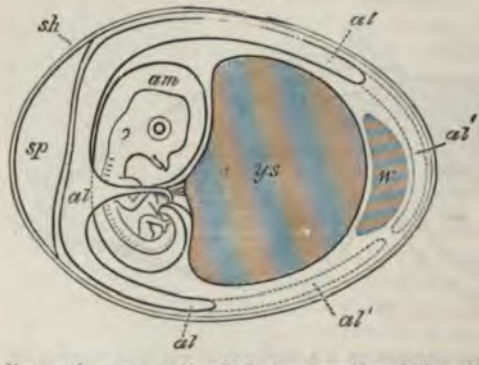


Fig. 661. — DIAGRAMMATIC OUTLINE OF A LONGITUDINAL SECTION OF THE FOWL'S EGG ABOUT THE MIDDLE OF INCUBATION. (A.T.)

sh, the shell and its membrane; *sp*, the air space much enlarged; *am*, the amnion with the enclosed embryo now placed towards the large end of the egg and air space; *ys*, the yolk and yolk-sac; *al*, the allantois expanded as a doubled vesicular membrane over a considerable part of the internal surface of the egg; *al'*, in dotted lines indicates the manner in which its expanding folds will ultimately meet and cover the whole of the deeper parts; *w*, the hardened remains of the white or albumen which towards the end of incubation lie between the yolk-sac and the allantois.

exhibit in the arteries and veins a marked difference of colour which indicates the action of the air upon the blood through the egg-coverings analogous to that of a respiratory organ.

It is also worthy of notice that from the time when the allantois has attained some size, it, like the amnion, is possessed of contractility, which resides in its mesoblastic layer; and accordingly on opening an incubated egg, from the effect of change of temperature or other stimuli, active motions may be perceived, caused by the alternate contraction and relaxation of different parts of the membrane.

In some of the mammalia the origin and early development of the allantois is nearly the same as in birds, but in a more advanced stage of development the relations of this membrane to the other parts of the ovum are greatly modified by its combination with the chorion, more especially in the region of the placenta.

In most mammals the external or mesoblastic lamina of the allantois undergoes greater extension than the inner hypoblastic sac, and this is remarkably the case in the human subject, in which it is still doubtful whether any internal vesicle is present beyond the limits of the umbilical cord. In the human ovum the external or mesoblastic vascular element probably spreads at a very early period over the whole interior of the chorion (placental and non-placental parts), while the internal or hypo-

blastic vesicle either shrinks and atrophies at a very early period or is comparatively small and has never reached the interior of the chorion. This subject will again be referred to in the account of human utero-gestation.

Fig. 662.

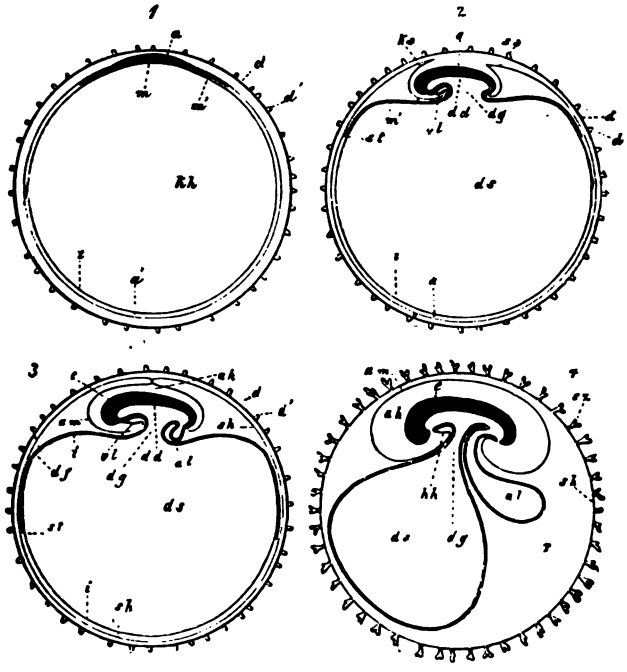


Fig. 662.—Diagrammatic sections of the mammiferous ovum in different stages of development to show the progress of formation of the membranes. (From Kölliker.)

1. Ovum in which the chorion has begun to be formed, with the blastoderm and rudiment of the embryo within. 2. Ovum in which the cephalic and caudal folds have contracted the umbilical aperture towards the yolk-sac, and the amniotic folds are turning towards the dorsal aspect. 3. The amniotic folds being completed have met in the dorsal region; the umbilical opening is more contracted, and the allantois has begun to sprout. 4. The true amnion is detached from the reflected or false amnion which has disappeared or combined with the chorion; the cavity of the amnion is more distended; the yolk-sac is now pediculated, the allantois projects into the space between amnion, chorion, and yolk-sac, and the villi of the chorion begin to ramify.

d, external membrane or primitive chorion; *d'*, commencing villi of the chorion; *sh*, subzonal membrane or chorion; *sz*, villi of the chorion more advanced; *am*, amnion: *ah*, its cavity; *ks*, cephalic fold; *ss*, caudal fold of the amnion; *a*, the embryonal rudiment in the epiblast; *m*, that in the hypoblast, and *m'*, in the mesoblast; *st*, margin of the vascular area in its early stages; *dd*, hypoblast; *kh*, hollow of the vesicular blastoderm, becoming afterwards *ds*, the hollow of the yolk-sac; *dg*, ductus vitello-intestinalis; *al*, allantois; *e*, embryo; *r*, original space between amnion and chorion; *vl*, wall of the thorax in the region of the heart; *hh*, pericardial cavity.

The urinary bladder of mammals is produced by a dilatation in the pedicle of the allantois near the cloaca and within the body of the embryo. The urachus is the tubular extension of the walls of the bladder towards and in part through the umbilicus to join the allantois,

but the extent to which its hollow is prolonged varies greatly among animals, and in the human embryo this does not in general pass beyond the root of the umbilical cord.

The Chorion.—Under this name there has been long known in human embryology a most characteristic but rather complex membrane which surrounds the ovum from the earliest period at which it has been observed within the cavity of the uterus, and which probably begins to be formed about the ninth or tenth day after conception. This is the villous or shaggy vascular chorion, a part of which takes an important share by its further development in the formation of the fœtal portion of the placenta, while the remainder may be recognised as persistent during the whole of uterogestation.

An external covering of the ovum having a very similar origin and structure, and with analogous relations to the other parts, exists for a time in all mammals, and though in many less developed and less persistent than in the human ovum, still deserves the same name.

The mammiferous ovum when it enters the uterus has still a covering from the ovarian zona pellucida, but in the rapid expansion which the blastodermic vesicle undergoes within the first or second day after the completion of the segmenting process, the zona seems either to be much attenuated and finally lost, or may possibly be combined with the outer layer of the blastoderm, which then surrounds the whole ovum. In some animals, such as the rabbit, dog, and cat, and the same is probably the case in man, previous to the appearance of any trace of the embryo, but when an embryonic area may have been formed, villi begin to project from the surface of the ovum, and from the primitive cellular structure of the villi it is almost certain that they proceed from the outer layer of the blastodermic vesicle, to which therefore must be mainly attributed the first origin of the chorion. These villi extend over a large portion of the surface, perhaps only excepting the embryonic area and a part of the ovum where it is not in contact with the uterine wall. They are at first destitute of blood-vessels and are of simple cellular structure. They soon become pervaded in their interior by connective fibro-nuclear tissue derived from the mesoblast, which extends itself below the primitive epiblast. Some time later or after the development of the vascular membranes of the yolk and allantois, and after the completion of the fold of the amnion and the separation of the false amnion, the villi acquire blood-vessels which penetrate the connective tissue of their interior, and are in some animals wholly, in others partially derived from those of the allantois; in the latter case, as before stated, the chorion receives blood-vessels also from the yolk-sac.

In birds the separation of the parietal and visceral mesoblast, and the intervention of the allantois between them, leads to the formation of an external membrane, composed of epiblast and parietal mesoblast, which lies close to the outer covering of the egg; but this membrane afterwards unites with the visceral mesoblastic layer of the allantois and thus loses its independence.

In mammals, however, this external membrane formed of the false amnion and its peripheral continuation in the blastodermic vesicle constitutes the basis of the chorion, and is the same as that to which Turner proposes to give the name of *subzonal membrane*.

The further history of the development of the chorion will be given in connection with the formation and structure of the placenta, but

nsly to entering upon that subject, it will be proper at this place
e some account of the early development of the human ovum and
o.

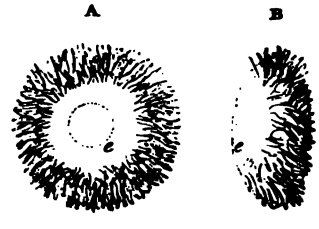
HUMAN UTEROGESTATION.

Early Stages of the Human Ovum.—Great obstacles have
in the way of the study of the earlier stages of the development
human embryo and its membranes from the extreme rarity of
portunities for observing the ovum in perfectly natural conditions
the uterus after death, and from the frequency of abnormal
es in aborted products in the first two months of pregnancy.
n the last few years, however, some important contributions have
nade to the knowledge of this subject, among which is deserving
cial notice the elaborate Monograph, by Professor His, in which
new information is supplied and the first systematic attempt has
nade to investigate the human embryo by the method of sections
132, 1880–82).

e impregnated ovum has never been detected in the course of its
it through the Fallopian tubes of the human female. From the
gy of animals and some observations on the changes in the uterus
elieved that the human ovum may arrive in that cavity at the
th or eighth day after impregnation, but although instances are
led in which at the eighth day a delicate vesicular body was found
lly imbedded in the inner wall of the uterus, which from the pro-
ty of impregnation having taken place might possibly be an ovum,
ese bodies were not observed with sufficient accuracy to determine
nature, and it does not appear that the human ovum has been with
nty distinguished in the uterus before the tenth or twelfth day.

a certain number of such observations the ova were found to
attained the size of a small pea or nearly a quarter of an inch in
ter, and were already more or less beset with villi on the outer

Fig. 663.



3.—FRONT AND SIDE VIEWS OF AN EARLY
AN OVUM FOUR TIMES THE NATURAL SIZE
a Reichert).

ovum is supposed to be of thirteen days
apregnation. The surface bare of villi is
xt the wall of the uterus, showing at *e*,
acity produced by the thickened em-
disc. The villi covered chiefly the
al parts of the surface.

e of the chorion; no embryo
o be seen in these cases, nor such
icture of the membranes as to
it probable that the process of embryonic development had made
dvance.

e case of this kind deserves especial notice from the very favourable
nstances under which it was examined (Reichert, 1873, No. 125).
as found in the uterus of a woman who committed suicide, and
the facts known as to her history it was believed by Reichert to
twelve or thirteen days after conception. Its largest diameter was
m. Its shape was that of a flattened spheroid, and the simple villi
h partially beset its surface extended mainly over the equatorial
ins, and left the two flatter surfaces bare to the extent of 2·5 mm.,

or $\frac{1}{10}$th of an inch. No traces were anywhere to be detected of an embryo; but the membrane of the ovum from which the villosities sprang was of cellular structure, and in the middle of the smooth part, turned towards the uterus, there was an opaque spot which might be taken for an embryonic area, and which presented internally a thin layer of finely granular nucleated cells. The ovum lay on the inside of the posterior surface of the uterus near the upper border, imbedded in the thickened mucous membrane or decidua, and having a thin covering of the same substance, which with the included ovum formed a rounded projection into the cavity of the uterus.

It may be doubtful how far the process of development had advanced

Fig. 664. Fig. 665.

Fig. 664.—Human ovum of 12 to 13 days (from Allen Thomson).

1. The ovum of the natural size with simply villous chorion.
2. The same opened and magnified seven times. The large yolk-sac is seen with the embryo seen sidewise lying flat upon the yolk-sac.

Fig. 665.—Human ovum and Embryo of about 14 days (from Allen Thomson).

A. The ovum opened, half the chorion laid to one side and the embryo and yolk-sac seen in the other; natural size.

B. The embryo and yolk-sac viewed from the dorsal aspect, magnified about ten times; *a*, yolk-sac; *b*, hind brain portion; here for a space the medullary canal is closed; *c*, the mid-brain open superiorly; *d*, hinder part of the medullary canal also open; *e*, portion of membrane, perhaps belonging to the torn amnion.

in this ovum, but supposing Reichert to be correct in holding that no parts of the embryo had yet been formed, it would appear that in the human embryo villi may be developed from the blastoderm, as occurs in some animals, previous to the formation of a reflected amnion.

A somewhat similar case was observed by T. Wharton Jones (No. 118), in which also the side next the uterus was devoid of villi and there was no appearance of an embryo. Another instance observed by Bruns presented nearly the same phenomena. (No. 126).

The first appearance of the human embryo as a primitive trace, or with a simple medullary groove, has not been observed. Among the earliest human ova in which features of embryonic structure are distinctly recognisable are two first described by the writer of this section in 1839 (No. 119), and another described by His (No. 132), which may have been even of a slightly earlier date.

In this stage the embryo, which consists almost entirely of its primary axial parts, lies prone on the surface of the yolk-sac, after the

manner of a chick on the second day or the rabbit on the tenth. The heart exists, and doubtless a vascular area on the surface of the yolk-sac, though not fully observed, was already the seat of the first circulation. From the researches of His it seems probable that in the two

Fig. 666.

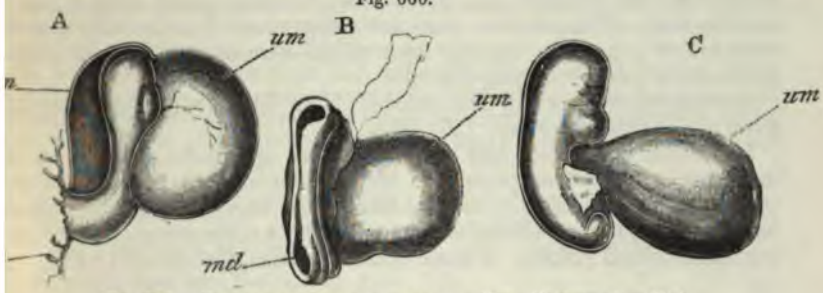


Fig. 666.—THREE EARLY HUMAN EMBRYOES (from Balfour after His).

A. An embryo of less than fourteen days, described by His. *am*, amnion; *um*, umbilical vesicle; *ch*, chorion to which the embryo is attached by a stalk.

B. Embryo of about fourteen days, described by Allen Thomson. *um*, umbilical vesicle; *md*, medullary groove.

C. Embryo of sixteen or eighteen days, described by His. *um*, umbilical vesicle.

first mentioned specimens, the amnion, although imperfectly observed nevertheless already existed, but had been accidentally destroyed, and His is of opinion that in these and other similar cases the allantois, which in the human ovum is undoubtedly formed at a very early period, had

Fig. 667.—HUMAN EMBRYO OF 15—18 DAYS, WITH YOLK-SAC, AMNION AND UMBILICAL PEDICLE. Magnified (from Kölliker after Coste).

b, aortic bulb; *c*, heart; *d*, margin of the wide abdominal opening; *e*, œsophagus; *f*, branchial arches; *i*, hind-gut; *n*, *m*, vitelline vessels; *o*, yolk-sac, its vessels not fully represented; *u*, stalk of allantois; *a*, allantois with distinct vessels forming a short umbilical cord united to chorion; *v*, amnion; *ah*, its cavity; *ch*, chorion.

Fig. 667.

already grown out from the hinder part of the body of the embryo so as to become attached to the interior of the chorion, as illustrated by the accompanying diagram. (Fig. 670.)

Somewhat more advanced than the foregoing is the ovum well described by Coste (No. 22, iii.), which was probably of from fifteen to eighteen days, and of which the whole diameter was 13 mm., or fully half an inch. The embryo, of 4·4 mm. in length, lay upon a vitelline sack at one side of the cavity within the chorion, and was there fixed by an umbilical cord to the interior of that membrane, while a

distinct amnion enveloped its other side. The parts of the heart with the pericardium were distinctly recognisable, as well as several other points of structure belonging to the embryo, which will be referred to at a later period. The cephalic portion of the intestine was formed and enclosed, but the larger hinder part was no more than a groove opening widely into the yolk-sac (fig. 667). The vitelline vessels were distinct on this last. The chorion was uniformly covered with villi, which were hollow; and the vascular layer of the allantois ran inside it without however yet penetrating the villi.

An embryo described by His, marked L in his Monograph, presents some of the same features. (Fig. 666, A.)

In human ova which may be estimated as approaching the term of three weeks after conception, the body of the embryo is found to be curved, the cephalic flexure has also taken place, several of the pharyngeal bars and clefts appear below the cranium, and the communication between the intestine and yolk-sac is much reduced in size, though still wide.

Fig. 668. Fig 669.

Fig. 668.—Outline of human embryo of about three weeks. ½ (A.T.)

Fig. 669.—Outline of human embryo of about four weeks. ½ (A.T.)

am, amnion; *uv*, yolk-sac; *al*, allantoid pedicle; *ae*, anterior extremity; *pe*, posterior extremity; *h*, heart.

In the next stage, of which the age may be reckoned as of fully three weeks (see fig. 668), the extremities begin to appear as semi-circular plates projecting from the lateral ridge of the body. The Wolffian bodies are formed, the visceral arches are now four in number, including that of the lower jaw, with the clefts between them, the intestine has become tubular and the vitello-intestinal communication is diminished in width. At four weeks (fig. 669) these features are more pronounced, the yolk-sac is pyriform, its duct is thin and elongated, and the extremities begin to divide into proximal and middle segments.

In the earliest stage at which the human embryo has been observed, or near the end of the second week, the symmetrical rudiments of the body lie prone upon the surface of the yolk-sac enclosed in an amnion and with an allantoid adhesion to the chorion. In the course of the third week, the midgut becoming more and more tubular, the head and trunk of the embryo undergoing incurvation, and the abdominal walls converging ventrally, the umbilical aperture, which is at first very wide, contracts and embraces more closely the diminishing vitelline duct and the allantoid vessels; and by the sixth week the amnion, which was at first very close to the body of the embryo, is separated from it by

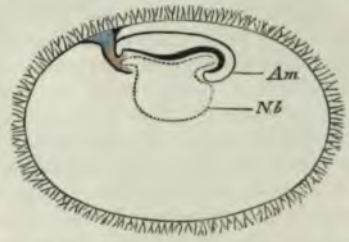
the increase of the amniotic fluid, and the umbilical attachment begins to elongate into a cord over which the amnion is inflected.

Up to this time the human embryo presents a remarkable resemblance to that of most mammals, and also to some extent of birds and reptiles of a corresponding stage of development; but in the period which follows, or from the sixth to the eighth and still more to the tenth weeks, the changes which it undergoes, though agreeing in their general nature with those which take place in other animals, are so modified as gradually to bring out the peculiar features which are characteristic of the human form and type of organisation. Among these the most marked are the large and early development of the cerebral hemispheres which gives peculiar prominence to the forehead and upper part of the head, together with the comparative small size of the maxillary and mandibular parts of the face, the form of the external auricle, and the form and attitude of the limbs.

Fig. 670.—Diagrammatic section of the early human ovum according to His. (From Balfour after His).

Am, amnion; *Nb*, umbilical vesicle.

Fig. 670.



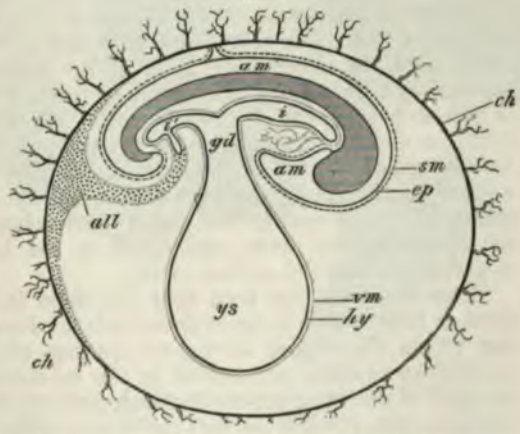
It would have been desirable to give some account at this place of the rate of progress and the peculiarities of form and structure belonging to the successive stages of early growth and development in the human embryo; but the want of space and the paucity of materials for such an account as would be satisfactory forbid the attempt for the present, and oblige us to refer the reader to the useful plates of Erdl (No. 23), and to the important contribution to the subject made by His in the second part of his work on the human embryo (No. 132).

Returning to the subject of human uterogestation it is to be observed that the mode in which the connection of the embryo with the chorion is established by the allantoid pedicle and vessels, as well as the early condition of the amnion, present some peculiarities of which direct observations have not yet furnished a full explanation, or one which would bring the phenomena into conformity with the modes of development of the membranes hitherto most familiar to embryologists. But several recent observations seem to show that important deviations from the better known types of development among mammals may still be discovered by future investigations.

Fig. 671.—Diagrammatic outline of section of human ovum at three weeks (A. T.)

ch, chorion; *ep*, epiblast of reflected amnion; *sm*, parietal mesoblast; *am*, amnion; *ys*, yolk-sac; *all*, allantois; *vm*, visceral mesoblast (vascular layer); *hy*, hypoblast.

Fig. 671.



The view taken by His (No. 132. I.) that the outer layer of the human allantois is from a very early period in close proximity to, if not in actual union with the primitive chorion, would not be inconsistent with what is already known of the development of the membranes in most animals, if it could be supposed, as seems

necessary, that the mesoblast of the allantois extends itself in the intermesoblastic space, and is therefore at first within a caudal or equivalent fold of the amnion. It is difficult indeed to conceive how the vascular layer of the allantois could pass round the whole interior of the chorion, except in a space formed between the outer and inner folds of the amnion.

Schäfer's observations in the guinea pig (No. 100, ii.) and Fraser's in the Rodentia, sufficiently show how early the vascular layer of the allantois may extend itself towards the chorion in some tribes of animals, and the researches of His on early human ova, as well as those of Coste and others go far to prove the early union in a peculiar manner of the outer layer of this membrane with the chorion.

2. **Enclosure of the Ovum in the Uterine Decidua.**—It is now well known that the uterus is prepared for the advent of the ovum by the increased development of certain parts of its mucous membrane which give rise to the decidua.

A similar change takes place previous to every menstrual period, but in case of pregnancy occurring there is no exfoliation of the membrane such as follows in menstruation, but on the contrary the development of the decidual elements of the mucous membrane progresses to a much greater degree. These changes are probably of two kinds, the first consisting mainly in the increase of the subepithelial cellular elements of the mucous membrane, together with a dilatation and subsequent atrophy of parts of the utricular glands, and the other in a great enlargement and change of structure of the uterine blood-vessels, which together prepare the way for the formation of the maternal part of the placenta in the more limited area occupied by that structure.

Embryologists were for long at a loss to understand how the human ovum, which enters the cavity of the uterus quite free from any reduplication of the uterine lining membrane, becomes very soon completely enclosed, or *incapsulated* in its substance. Nor have the actual steps of the incapsulation ever yet been directly observed. But the fuller knowledge of the nature of the change which the lining membrane of the uterus undergoes before and after the arrival of the ovum in its cavity, and the closer observation of the nature and relations of the material by which the ovum is enclosed make it extremely probable that, as was first suggested by Sharpey (No. 15, iii., p. 1580), the minute ovum, on entering the uterine cavity, and possibly being sunk in one of the depressions which lie between the bulging areas of hypertrophied mucous membrane, is gradually surrounded by a wall of the decidual substance, which rising from below encroaches more and more upon the surface of the ovum, and comes at last to cover it entirely and to exclude it from the uterine cavity.

When the ovum has been fully imbedded in the decidua, as at the third or fourth week, it forms along with the decidua a swelling or projection within the uterine cavity, on opening which the villous chorion is found everywhere surrounded by the substance of the decidua; but the part of the latter substance which passes over the free surface of the ovum, or that which is towards the uterine cavity, is thinner and simpler in its structure than at the place of attachment of the ovum and in other parts of the uterine surface; and its appearance at the most projecting part or summit, different from the rest, indicates, by a sort of cicatricial mark, the place where the substance of the decidua, as it gradually covered in the ovum, may be supposed to have finally closed.

The decidual thickening of the mucous membrane affects nearly equally the whole of the lining of the uterine cavity, but towards the os

rnum, and across the fundus to the Fallopian tubes, the thickening, suddenly and then gradually, decreases, and the membrane assumes unaltered condition which is maintained in these passages.

By the changes now described there has become apparent the distinc-

Fig. 672.

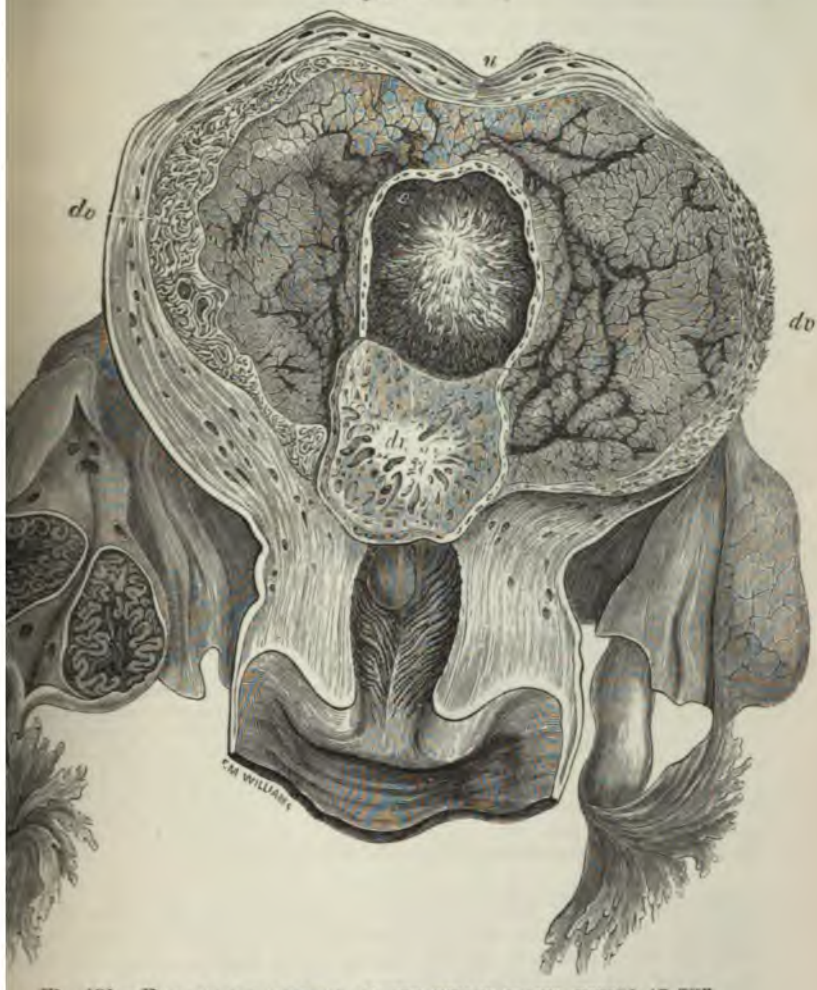


Fig. 672.—VIEW OF THE INTERIOR OF THE HUMAN GRAVID UTERUS AT THE TWENTY-FIFTH DAY (from Farre after Coste).

u, uterine wall; *o*, villi of the chorion of the ovum; *dv*, decidua vera and enlarged erine glands; *dr*, decidua reflexa, divided round the margin of the ovum, and turned wn so as to expose its pitted surface, which has been removed from the ovum. The ght ovary is divided, and shows in section the plicated condition of the early corpus teum.

on of the three portions of decidua usually recognised by authors, viz., *cidua vera*, *reflexa*, and *serotina*. The first of these is that portion of e *altered membrane which lines* the general cavity of the uterus in

every part except that occupied by the attachment of the ovum; the decidua reflexa is that which covers the ovum as it projects into the uterine cavity, and which is continuous with the decidua vera round the base of the swelling. The name of *decidua serotina* (or late formed) is most frequently employed to denote the layer or layers of decidual substance which intervene between the developed placenta and the uterine wall outside it; but by some it has been made to include also the part of this structure which originally enters into the formation of the maternal part of the placenta, thus including a placental and a uterine decidua serotina.

Fig. 673.

Fig. 673. — SEMI-DIAGRAMMATIC OUTLINE OF AN ANTERO-POSTERIOR SECTION OF THE GRAVID UTERUS AND OVUM OF FIVE WEEKS (A.T.).

This drawing is taken from a very perfect specimen of the uterus obtained from the body of a woman who died of cholera in 1849.

a, anterior uterine wall inside which was situated the placental attachment of the ovum; *p*, posterior uterine wall (the accessory parts being omitted); *m*, muscular substance of the wall; *c*, thickened lining membrane forming decidua vera, and showing grooves and eminences on its surface and enlarged glands and vessels in its substance; *g*, the glandular or deep layer; *r*, the decidua reflexa; *u*, indicates the uterine cavity; *s*, decidua serotina; *c*, cavity of the cervix uteri; *ch*, chorion with its villi, which are more highly developed on the placental side; *e*, the embryo enclosed in the amnion, with the allantoic vessels passing into the placenta, and the umbilical vesicle.

The blood-vessels and the glands of the mucous membrane also undergo great enlargement and modification. The whole of the decidua vera and the adjoining part of the reflexa are at first penetrated by blood-vessels derived from those of the uterus, more especially in the latter part of the second month, when the decidual structure may be considered as having reached its highest degree of development. After this time the blood-vessels of the decidua reflexa, and later those of the whole lining decidua of the uterus, except in the immediate vicinity of the placenta, shrink and ultimately disappear, so that the membrane formed by the united deciduæ becomes in the end wholly non-vascular. The same retrograde process, leading to atrophy and disappearance, occurs in the blood-vessels of the chorionic villi by which the decidua reflexa is penetrated, and, although the villi themselves never entirely disappear, but may be

traced even in the advanced stages of pregnancy as sparse and shrivelled irregular arborescent processes, the blood-vessels very soon begin to shrink and disappear from all the villi which do not form part of the placental structure. To the changes occurring in the decidua serotina as connected with the placenta reference will be made further on.

The Placenta.—The general relations of the fœtal and maternal structures of the human placenta are illustrated in an interesting manner

Fig. 674.

Fig. 674.—Chorionic villus from the placenta at the twelfth week. Enlarged 180 diameters (from Leishman after Ecker).

From *a* to *b*, the epithelial covering is left entire; from *a* to *a* it has been removed and the fibrous core with the capillary blood-vessels is shown.

by the study of the different forms which they present in various orders of mammals, or as it is called of their *placentation*; but limitation of space prevents our entering upon any full account of this subject, and the reader is referred to the works of Turner (No. 150, ii.), Ercolani (No. 147, iv.), and other authors.

The general result of recent researches on the Comparative Anatomy of the placenta may be thus stated. In all mammals, so far as is yet known, excepting the monotremata and marsupials, the true placental structures consist in the establishment of a close relation between finely ramified fœtal blood-vessels derived originally from the outer or mesoblastic layer of the allantois, with minutely or widely distributed blood-vessels belonging to the uterus. Both of these are originally at least, if not throughout the whole of gestation, accompanied and supported by cellular and other constituent elements of the fœtal and maternal structures to which the blood-vessels respectively belong; as, on the part of the fœtus, the villous ramifications of the chorion, and on the side of the mother a corresponding development of a part of the lining membrane of the uterus; while the uterine glands do not appear to take any direct or important part in this combination of fœtal and maternal elements.

a. Early Development of the Human Placenta.—The human placenta and that of the Apes are characterised, 1st, by the fact that the chorion derives its blood-vessels exclusively from the allantois, which are ramified in the villi to a very great extent and degree of minuteness, and, 2nd, by the enormous dilatation of the uterine vessels, and the very marked changes undergone by the decidual or perivascular tissue, which give rise to a structure different from that of any other animal.

All are now nearly agreed on general grounds that some combination of fœtal and maternal parts occurs in the formation of the placenta; but we are still far from having an exact knowledge of the manner in which the union is effected. Sufficient observations are in fact wanting to show in a series the successive conditions of the placenta during the period of most active change, *i.e.*, from the 5th or 6th week up to the

middle or end of the third month ; and as the human placenta differs too widely from that of animals to admit of analogical reasoning, the views of authors who have offered explanations of the phenomena must, to a great extent, be regarded only in the light of more or less probable conjectures.

Numerous observations, however, would appear to make it extremely probable, if not actually a demonstrated fact, that an actual imbedding of a part or the whole of the fœtal villi in the substance of the decidua is a fundamental phenomenon in human placental formation (Schröder van der Kolk (No. 141), Langhans (No. 151, i. and ii.), Leopold (No. 156)), &c.

Fig. 675.

Fig. 675.—Vertical Section through the middle part of the Placenta and the Uterine Wall (from Farre after Wagner).

The preparation was from a woman who died in the thirteenth week of gestation : the lines *u*, *u*, run through the wall of the uterus to the outer surface of the placenta ; *d*, the decidua serotina ; *p*, the tufts of fœtal vascular villi, of which two larger divisions are separated by decidual septa, as at *dp* ; *f*, the placental end of the umbilical cord ; *am*, the amnion ; *ch*, the chorion ; *vf*, divided fœtal blood-vessels ; *v*, stems of vascular villi ; *us*, uterine sinuses or veins ; *a*, *a*, coiled arteries passing into the placenta.

The writer of this section thinks that he has obtained convincing proof of this imbedding in the specimen represented in fig. 673, as well as in others of a somewhat more advanced age (7 weeks) ; and, in the figure referred to, he has indicated the place and manner in which the imbedding of the villi may be supposed to occur by faint lines in the shaded space or interval represented between the tufts of villi and the firmer decidua in the region of the decidua serotina and the greater part of the reflexa.

Thus the villi become everywhere covered by or brought into close connection with delicate prolongations of altered decidual tissue, carrying with it loosely the much expanded uterine vessels reduced to the condition of gigantic capillaries.

But the main difficulty is to determine what afterwards becomes of

this decidual tissue, and what is the relation of the nascent condition of the placenta to its fully developed structure; and here, therefore, the principal divergence of opinion among authors arises; some holding, as Kölliker does, that the maternal elements, after having been combined with the villi in the manner before indicated, undergo atrophy and disappear so as to leave the fœtal villi provided only with their chorionic structures, and thus hanging naked into the maternal blood sinuses; and others, such as Ercolani, and in some measure also Turner, maintaining that a part of the maternal structure remains as a permanent covering of the villi, and that, after the acquisition of these new maternal elements, the original chorionic epithelium of the villi has disappeared in a greater or less degree. The writer is in the meantime most disposed to give the preference to the view advocated by Kölliker.

In this early process of development of the placenta it will be understood that the fœtal villi increase rapidly in their number, the complexity of their ramification, and the penetration of larger and smaller blood-vessels through all their branches. This development affects at first all the villi of the chorion except those near the most projecting part of the reflexa; but in the fourth and fifth weeks the increase in the number and bulk of the villi becomes much greater on the side next the uterus where the placenta is about to be formed.

In the decidua serotina, on the other hand, great differences have become apparent, among which is to be noted its division into two layers by large spaces which are probably dilated glands. The inner of these layers, which may be called placental, soon loses its glands entirely, and the other, the uterine or glandular, retains a considerable amount of glandular structure.

The maternal blood-vessels of the inner serotina, which at first had the ordinary characters of the arteries, veins, and capillaries of the lining membrane of the uterus, become completely altered by the atrophy and disappearance of the external and middle coats from the larger vessels, and by the conversion of them all into wide lacunæ or gigantic capillaries through which the maternal blood continues to flow. These lacunæ retain for a time their epithelial lining, but finally, when the interpenetration of the fœtal and maternal part is complete, the epithelium is lost to view, and is therefore either entirely absorbed, or, as supposed by some, remains as a delicate or homogeneous covering of the exterior of the villi.

In the early stages of placental growth the villi show frequent attachment to each other and to the decidual septa by means of processes which appear to consist of a degenerated granular form of the decidual tissue, and are probably the remains of the imbedding decidua.

The chorionic villi, in becoming imbedded in the decidua, lie first loosely in groups within honey-comb-like loculi hollowed out of the chorionic surface of the inner serotina. They undergo the further union and imbedding mainly by being overrun by the looser substance of the decidua, as supposed by the writer, and the walls of the loculi formed of the firmer decidua probably extend themselves in the form of the septa between the lobes.

In this part of the decidua the glands, which undergo a remarkable enlargement (see later) in the decidua vera, speedily disappear, and it is now well ascertained in animals, by the researches of Ercolani and Turner, that the fœtal villi do not, as was once supposed, penetrate into

the dilated cavities of the uterine glands, but are sunk in crypts of the decidua which lie between the glandular orifices. Nor is there any reason to believe that the villi enter the uterine glands in the formation of the human placenta. On the contrary, the observations of Schröder van der Kolk, Kölliker, Turner and others are quite opposed to such a view.

b. Structure of the Advanced Human Placenta.—After the middle of pregnancy, the placenta forms a large discoid or lenticular mass, of from four to five inches in its larger diameter and about three-quarters of an inch in thickness, interposed in a limited space between the fœtal membranes and the uterus. It presents a fœtal and a uterine surface, the

Fig. 676.

Fig. 676.—DIAGRAMMATIC REPRESENTATION OF A SECTION OF THE HUMAN PLACENTA NEAR THE MARGIN AT FIVE OR SIX MONTHS (slightly enlarged). (A. T.)

am, amnion; *ch*, chorion; *fv*, stems of fœtal vessels passing into two of the placental lobes in the villi of which they undergo capillary ramification; *m*, muscular wall of the uterus with divided arteries and veins; *v*, decidua vera; *r*, d. reflexa; *s*, decidua serotina placentalis; *s'*, d. serotina uterina; *ds*, septa of decidua passing from the serotina between the lobes, branching into their interior, and reaching the chorion; at their bases are seen the maternal coiled arteries and the divided veins; *cs*, circular sinus; *sch*, the subchorionic decidual layer. An attempt is made in this diagram to show the union between the penetrating processes of reticulated decidua serotina and the villi of the lobes, the union extending in this, which is a marginal part of the placenta, as far as the subchorionic layer of the decidua.

former having implanted into it, usually near the middle, the umbilical cord, containing the allantoic or umbilical vessels, and covered by a tubular prolongation of the amnion. The placenta continues to increase in size with the fœtus, and when it has attained its full dimensions, it has a width of from seven to eight inches, or even more, and a thickness of about one inch and a quarter. Towards the circumference it rapidly thins, where it becomes continuous with the chorion and decidua. The fœtal surface is

covered by the chorion and amnion, and is traversed by the larger divisions of the umbilical vessels before they dip into the substance. The uterine surface shows a subdivision into a number of large lobes, sometimes called cotyledons, which are covered with a layer of decidua serotina passing over the whole of this surface, and sending septal prolongations into the placenta between the lobes, which may be traced in some places as far as the fœtal surface.

The more uniform parenchyma of the placenta within these lobes, which to the naked eye presents the appearance of a minutely divided sponge, consists in greatest part of highly-developed and complicated tufts of fœtal villi which adhere to the chorion by vascular stems of considerable size and strength, and subdivide again and again into minute and complex ramifications. Between the innumerable subdivisions of these tufts are the irregular vascular spaces or lacunæ, the outlines of which follow closely the ramifications of the villi throughout every inflection of their surface. These spaces, which are filled with the maternal blood and are continuous with the uterine vessels, are doubtless to be regarded as belonging to the maternal system, but their minute structure and anatomical relations have been so greatly modified in the progress of the placental growth, that, as already stated, it has been found very difficult to determine their exact nature in the fully formed condition.

On its outer side the placenta is united to the uterine wall by the decidua serotina, consisting, as already mentioned, of two layers, of which the inner alone enters directly into the formation of the placenta. From this inner layer of the serotina septa are prolonged between and surround more or less completely the lobes, so as to separate them from one another with very obvious but interrupted bands of decidual tissue; and from these interlobular septa irregular branched processes run into the interior of the lobes and through the placenta, so as even to reach the chorion in many places, and to unite with the subchorionic layer of decidua which extends from the margin of the placenta upon the chorion for a considerable distance, if not over its whole placental surface; and it thus becomes apparent that both fœtal and maternal (or decidual) structures are intimately intermixed throughout the whole thickness of the placenta.

A minuter examination of the spongy or finely divided portions of the placental lobes shows that in these the innumerable terminal villi of the branched fœtal placental tufts lie or hang for the most part free in irregular spaces (intervillous lacunæ) filled with the maternal blood; but they are not entirely loose, for, beside the stalks on which they are set, in numerous places they are attached at their tips and also on their sides by slender bands and sometimes finer filaments of very irregular form and of a granular fibro-nuclear substance, which pass from one to another of the villi, and between them and the processes of the decidua serotina, and which seem to be composed of decidual elements; forming thus according to Turner a network of trabeculæ derived from the decidua serotina in the interspaces of which the villi are contained (150, iii.).

The maternal blood spaces present the most varied and irregular forms, which scarcely admit of description, and, as they all intercommunicate freely, may rather be compared to a labyrinth, the walls of which are entirely formed by the villi over which they are moulded; so

that it is obvious that the villi, with whatever covering they may possess, are in full contact with the maternal blood which permeates all the intervillous spaces or lacunæ.

The fœtal villi present from a very early period, and long before they have entered into any combination with the uterine structures, a distinct external covering of epithelium which may be called chorionic, and as soon as they become vascular their interior is occupied by a core of connective tissue in which the fine divisions of the allantoic vessels are imbedded. In the more advanced stages of placental growth an increase of the fœtal vessels corresponding with the prodigious ramification and extension of the villi takes place, and besides the deeper loops of capillary and other vessels which occupy the interior of the villi there is developed also a more superficial capillary network (Schröder van der Kolk, No. 141); but in other respects the individual or terminal villi do not appear on a superficial inspection to differ greatly from those of the earlier stages.

On the other hand, there is good reason for regarding the maternal blood-spaces of the advanced placenta as essentially enlarged and altered decidual blood-vessels; for though the whole steps of the process of conversion have not been traced with sufficient fulness or accuracy, we are not without evidence from observation (Virchow, No. 142, and Priestley, No. 144) that the intervillous lacunæ must owe their origin to the disappearance of the decidual arteries and veins as such and the enormous dilatation of their capillaries around the villi, and to the thinning away of the decidual tissue in which they were previously distributed.

Microscopic observation has shown that the peculiar coiled vessels which pass through the serotina as the prolongations of the uterine arteries are destitute of the middle and outer arterial coats, but are lined with epithelium, and open directly by sudden enlargement, and without the intervention of any capillary vessels, into the wide cavities of the placental sinuses, and further that these sinuses are brought into direct communication with the larger uterine veins by means of considerable venous canals, lined with epithelium, which pass in a slanting manner through the decidua serotina, as well as by others which join the venous plexus named the circular sinus situated round the margin of the placenta.

Relation of the Fœtal and Maternal Elements in the fully-developed Placenta.—Such being the history of the fœtal vessels, and the maternal blood-spaces in the placenta, there still remain the important and difficult questions which have been long discussed, and which have not yet received a satisfactory solution—viz., What has become of the decidual tissue, and the maternal vascular lining in the developed placenta? Have they been entirely removed by atrophy and absorption, or are they still persistent, and are their remains still to be found as coverings of the villi, or in any other form?

As holding the first of these views Virchow, Kölliker, and Leopold may be quoted; and as supporters of the second, Schröder van der Kolk, Ercolani, and Turner.

It would occupy too much space to attempt any review of the arguments adduced in favour of these opposite views; and we must therefore refer the reader to the works of the authors quoted in connection with this subject, remarking at the same time, that while the greatest share of probability seems on general grounds to belong to the first view, or that of Kölliker, viz., that the villi retain their original epithelium, and that the maternal structure must have suffered atrophy and disappearance; the other opinion is not w
evidence in its favour. And more especially if it co

asserts—and in this he is supported by Romiti (No. 157)—that in the villi of the tenth week both the fœtal and maternal epithelium are still present together, while the fœtal or deeper epithelium appears to be undergoing atrophy preparatory to its removal, the view taken by that author, that in the formation of the placenta the decidual cells are substituted for the fœtal epithelial covering, and possibly also that a thin layer, representing the lining epithelium of the maternal vessels, overlays it externally on the surface of the villi, might receive important confirmation.

But, as before remarked, further researches are still required in the period of placental development, extending from the fifth or sixth week onwards into the third and fourth months, to enable us to determine the precise manner in which the peculiar condition of the maternal sinuses in the human species and in Simiæ is brought about. There can be little doubt that this condition is essentially different from that which has been well shown by the researches of Turner and Ercolani to prevail in other animals, in which it appears that, along with the fœtal capillary blood-vessels, and the epithelium of the villi, there are always present distinct maternal elements, in the form of capillary or other vessels lined with epithelium, and a certain amount of obvious decidual tissue surrounding them.

Relation of the Uterine Glands to the Placenta.—It has already been stated that the villi do not penetrate into the uterine glands of the human placenta. These glands undergo, it is true, in the earlier three months of uterogestation great enlargement and modification of their form. In the decidua vera especially the enlarged state of the glands is well known and very apparent in the early months of pregnancy; but as the membrane thins out in the later months, they are much flattened and atrophied, but are not entirely lost. In the inner layer of the decidua serotina they very soon become obliterated and disappear, but in the outer or uterine layer their cavities remain in a much widened condition, though drawn out and flattened; and it seems as if they gave rise in part to the separation of the outer and inner layers, where the severance afterwards occurs in parturition. In the outer layer, however, the glands are preserved in such a state as to be capable of restoration after parturition in that part of the mucous membrane.

The outer layer of the serotina is also the principal seat of the development in the latter half of pregnancy of the largest or giant multinuclear cells, which are characteristic of that layer in man, as well as in many animals. In connection with these cells, it is proper to mention the important discovery made by Friedländer (No. 152), and confirmed by Leopold (No. 156), according to which it appears that the main veins of the serotina and the adjacent part of the uterine wall undergo in the later stage of pregnancy a process of gradual obliteration by the ingrowth of the giant cells into the interior of the veins—a process which begins in the eighth month, and goes on progressively up to the end of gestation, and which seems to have the effect of producing stagnation and stoppage of the passage of the blood through the veins, and may probably be a factor in the induction of the act of parturition.

Placental Circulation.—The existence of a distinct circulation of blood in the fœtal and in the maternal vessels of the placenta, discovered by the Hunters, has long been placed beyond doubt by the experimental investigations of all those who have injected the two sets of vessels with sufficient care and success. By artificial injections fluids can be made to pass from the umbilical arteries through the capillaries of the villi into the veins, or in the reverse direction from the veins into the arteries. Nor does there ever occur, except from ascertained accidental rupture of the vessels, either extravasation of the injected material into the intervening tissue, nor any escape into the maternal sinuses.

The result of artificial injection of the blood-vessels in the pregnant uterus equally demonstrates the nature of the circulation in the maternal part of the placenta, for it is easy to show by this method that a fluid thrown into the uterine arteries passes through the coiled vessels and fills all the maternal blood-spaces of the placenta, surrounding everywhere the chorionic or fœtal villi, and ... thence into the uterine veins by the slanting venous channels, the *utero-sinuses*, lined with epithelium, which issue from the placenta at its ... piercing the decidua serotina, and which are also very

numerous towards the circumference of the organ, where they are in communication with the venous plexus or so-called circular sinus. Some of these veins may even be traced for some distance into the placenta, in the septa of decidual substance, which are prolonged from the decidua serotina between the lobes (See Turner, Kölliker, and others).

Separation at Birth and Restoration of the Uterine Membrane.—In the act of birth a large part of the decidual structures which have been formed in human uterogestation, including that which is strictly placental, the whole of what remains of the d. reflexa and a considerable part of the d. vera, now fused into one thin covering of the chorion, are separated from the uterus, together with the fœtal placenta, the membranes, and all that belongs to the ovum. Thus in parturition, by the effect of uterine contraction, the fœtus is first expelled; the detached placenta follows, and carries with it the inner layer of serotina, the coiled arteries and the slanting veins being broken through; and come the inverted membranes of the ovum, together with the remains of decidua reflexa and part of the vera, which are finally peeled off the whole of the inside of the uterus. On the uterine surface a part of the decidua vera remains, and also the uterine decidua serotina lying next the muscular wall of the uterus. In this layer are imbedded the remains of the convoluted uterine glands, which extend outwards into the substance of the muscularis mucosæ. These are soon prolonged to the uterine cavity, a ciliated epithelial lining is formed on the inner surface, and the natural structure of the whole membrane is thus completely restored.

II. DEVELOPMENT OF THE SYSTEMS AND ORGANS OF THE EMBRYO.

It will be convenient to treat of this, which is the most extensive division of our subject, under the following sections, viz.:—1. The External Form and Framework of the Body; 2. The Nervous System; 3. The Vascular System; 4. The Alimentary Canal and Associated Organs; 5. The Urinary and Generative Organs.

I. EXTERNAL FRAMEWORK AND WALLS OF THE BODY; THE SKELETON, VOLUNTARY MUSCLES AND INTEGUMENTS.

In the most general morphological view of the development of the external frame-work of the body, its parts may be regarded as being moulded in certain definite relations according to the vertebrate type upon the cerebro-spinal nervous centre and its containing cranio-vertebral cavity, and in their commencement they present the form of body-segments or somites, which in the trunk correspond in number with the vertebræ, but in the head follow a somewhat different arrangement. It will be convenient to begin with a short statement of the earliest phenomena of the development of the embryonic axis.

1. FIRST RUDIMENTS OF THE EMBRYO.

These consist mainly of four parts which, named in the order of their commencement, are the primitive streak, the medullary canal, the notochord, and the protovertebral somites. The first of these is essentially a temporary and evanescent structure; the third, round which the column of vertebral bodies is formed, though also transitory, is somewhat more persistent than the first; the second and fourth, as the foundation of important organs, may be regarded as permanent.

The Primitive Streak or Trace.—The earliest indication of the tion of the embryo is in the *primitive streak* which appears about welfth hour of incubation in the chick, and on the seventh day in rum of the rabbit, in that part of the embryonic area which, with

Fig. 677.

7.—PYRIFORM TRANSPARENT AREA OF E CHICK'S BLASTODERM WITH THE IMITIVE GROOVE.

rimitive streak and groove; *af*, amold commencing; the darker shading he primitive streak indicates the exof the mesoblast.

nce to the position of the em- may be called the hinder, and also is the narrower part when rea has become pyriform. It ot at first a linear or elongated but begins as a comparatively sickle-like thickening of the derm at the margin of the onic area, and subsequently hes inwards upon the area, e form of a narrow strap-like opacity, as previously described 748. It is closely connected with the epiblast or upper layer, and rmation seems to consist more immediately in a proliferation of rom the lower surface of that layer which results in the develop- of the mesoblast or middle layer through the whole length of the tive streak, in which the epiblast and mesoblast are thus rendered mous.

Fig. 678.

8.—EMBRYONIC AREA FROM THE OVUM OF A BBIT OF EIGHT DAYS. ♀ (From Kölliker.)

border of the embryonic area; *pr*, primitive with groove.

the course of its formation the primitreak acquires a groove, the *primitive* , which arises from a depression in the st at its upper surface. This groove not usually extend to either end of treak, but presents near its anterior nity most frequently, but elsewhere nd somewhat variably in birds one or depressions which are found to run gh the blastoderm and indicate an interesting relation of the to the blastopore and neurenteric communication previously re- to (p. 759). The hypoblast takes no share in the produc- f the primitive streak, but runs across the area free and flat h it.

primitive streak and groove were at one time confounded with mmencement of the true cerebro-spinal axis; but it was shown by servations of Dursy in 1867 (No. 90), and has been fully proved s (No. 29, i.) and others following him, that it does not give rise y part of *the nervous centre* nor to any other important organ,

but on the contrary, is in a great measure transitory and evanescent in its nature; for though at first it indicates truly the direction of the embryonic axis, we shall find that it is thrust more and more backwards by the medullary and vertebral rudiments as they progressively grow in front of it, and it seems at last to be lost in the tissue below the caudal

Fig. 679.

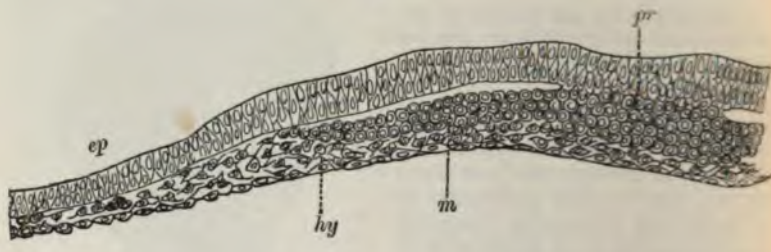


Fig. 679.—TRANSVERSE SECTION THROUGH THE FRONT END OF THE PRIMITIVE STREAK OF THE CHICK OF ABOUT 12 HOURS. (From Balfour.)

pr, primitive groove; *m*, mesoblast; *ep*, epiblast; *hy*, hypoblast.

extremity of the embryo. Its real significance therefore lies mainly in its relation to the origin and connection of the layers of the blastoderm and their apparent invagination at a period preceding the first development of the cerebro-spinal nervous axis of the embryo.

Fig. 680.

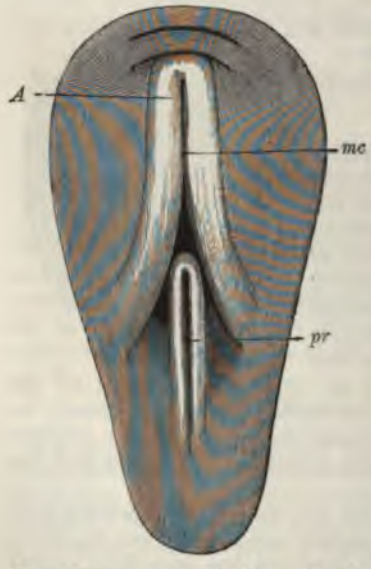


Fig. 680.—SURFACE VIEW OF THE TRANSPARENT AREA OF A BLASTODERM OF 18 HOURS, SOMEWHAT DIAGRAMMATIC. (From Balfour.)

pr, primitive groove, closed in front by the coalescence of the two lateral ridges; *mc*, medullary groove, having on each side the medullary folds or ridges, A, which also meet in front to enclose the groove, but diverge behind so as to enclose the primitive streak; in front the fold of the amnion is commencing.

2. **Medullary or Neural Centre.**—The first rudiment of the great neural centre makes its appearance somewhat later than the primitive streak, viz., in the chick about the eighteenth hour, and in the rabbit's ovum on the seventh day. It takes place entirely within the epiblast or outer layer, and depends on the growth of the cells of that layer in the anterior part of the embryonic area where it extends in the same direction as the primitive streak so as to occupy that part of the area left vacant by the latter.

The medullary plates which result from the thickening of the epiblast are at first comparatively short, corresponding mainly to that which will ultimately become the cephalic part of the nervous centre. They soon,

Fig. 681.

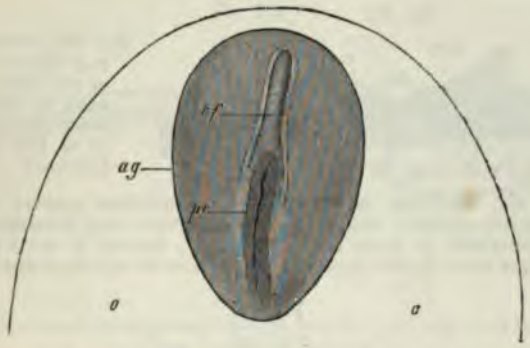


Fig. 681.—Embryonic area, with outline of the vascular area, from a rabbit's ovum of seven days. $\frac{35}{1}$ (From Kölliker.)

oo, vascular area; *ag*, embryonic area; *pr*, primitive streak and groove; *rf*, medullary groove.

however, elongate, and increasing in their thickness at the outer margins, they rise into lateral ridges, which are separated by a groove or furrow, while they run into one another, or are joined together round the cephalic extremity of the groove. Behind they diverge somewhat, and there they extend for some distance on either side of the primitive streak, so as to enclose nearly its anterior half between them.

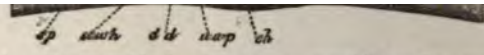
Fig. 682.—Dorsal view of a blastoderm and embryo chick having five mesoblastic somites. (From Balfour.)

a.pr, anterior part of the primitive streak; *p.pr*, posterior part; the medullary ridges have come together in the greater part of their extent, but have not yet united; the caudal swellings are visible on each side of *a.pr*.

Fig. 682.

As the formation of the medullary plates and groove progresses, they extend more and more backwards, so that the addition of new substance in the primitive or axial embryo takes place mainly by interposition between the part already formed and the primitive streak. As they extend backwards the ridges also rise more dorsally so as to deepen the groove, the cephalic part widens out into a somewhat conical hollow, while the spinal part remains of a more equable and smaller diameter.

In the next stage, which is completed by the 30th or 35th hour in the chick, and the 9th day in the rabbit, the medullary ridges of the epiblast bending round dorsally have met in the middle line above the medullary groove, and there coalesce, at first in a limited space near the



h, epiblast; *dd*, hypoblast; *sp*, mesoblast; *Pv*, medullary plates; *ch*, chorda dorsalis; *uwp*, proto-vertebral plate; *uwl* sion of mesoblast into its upper and lower laminæ; between laminæ or ridges which by their approximation close in the med

Fig. 684.

Fig. 684.—TRANSVERSE SECTION OF AN EMBRYO CHICK IN THE LA DAY, AT THE PLACE WHERE THE VERTEBRAL SOMITES CEASE.

rw, dorsal ridges: *rf*, medullary groove or canal beginni vertebral plate; *sp*, lateral plate of the mesoblast; *h*, epib primitive right aorta; *sp*, commencement of division of the body cavity.

Fig. 685.

anterior extremity of the primitive streak to the front of the medullary canal; but, except at its hinder end, it has no immediate connection with the epiblast in which that canal is formed, and lies beneath it in the place which is afterwards occupied by the bodies of the vertebræ

Fig. 686.

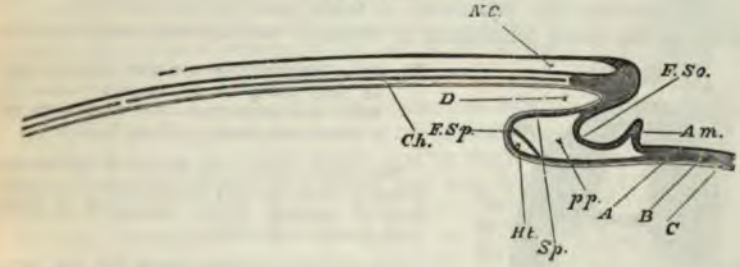


Fig. 686.—DIAGRAMMATIC LONGITUDINAL SECTION THROUGH THE AXIS OF AN EMBRYO-CHICK. (From Foster and Balfour.)

The section is supposed to be made at a time when the head-fold has commenced, but the tail-fold has not yet appeared. *A*, epiblast; *B*, mesoblast; *C*, hypoblast; *FSo*, fold of the somatopleure; *FSp*, fold of the splanchnopleure; *Am*, commencing (head) fold of the amnion: *NC*, neural canal, closed in front, but still open behind; *Ch*, notochord,—in front of it, uncleft mesoblast in the base of the cranium; *D*, the commencing foregut, or alimentary canal; *Ht*, heart; *pp*, pleuro-peritoneal cavity.

and base of the cranium. When fully formed it is also separate from the hypoblast which runs across below it. From this it might appear at first sight that it belongs to the mesoblast, by a part of which it is somewhat later surrounded. But there are still doubts with respect to its origin, that is, whether it is from the mesoblast or hypoblast. The former view is held by Kölliker, and for the higher vertebrates is in

Fig. 687.

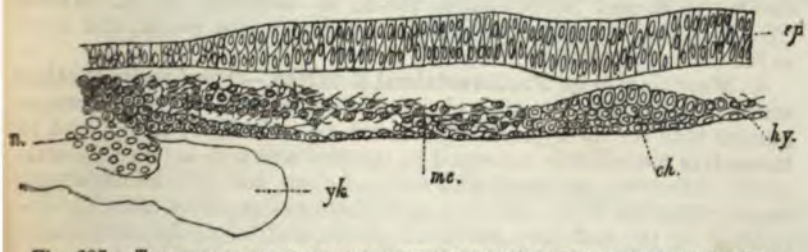


Fig. 687.—TRANSVERSE SECTION THROUGH THE EMBRYONIC REGION OF THE BLASTODERM OF A CHICK AT THE TIME OF THE FORMATION OF THE NOTOCHORD. (From Balfour.)

ep, epiblast; *hy*, hypoblast; *ch*, notochord; *me*, mesoblast; *n*, nuclei of the germinal wall *yk*.

some respects tenable: but in elasmobranchs Balfour has found the notochord to *arise* very distinctly from the lower layer by an actual infolding of a linear strip of the cells of that layer, and he, as well as some others, are disposed to attribute the origin of the notochord in the amniota to a similar source. With respect to this view,

it is to be observed that the hinder end of the notochord is direct continuous with the front part of the primitive streak where the mesoblast and epiblast are united, and if it does spring from the lower layer in front of that, it is still possible that in that situation the mesoblastic elements have not yet been differentiated from the hypoblast in the primitive lower layer.

In the amniota the notochord is mainly cellular in structure; but in some of the lower vertebrates it becomes cartilaginous, and remains

Fig. 688.

Fig. 688.—SECTION THROUGH THE HINDER PART OF THE TRUNK OF AN EMBRYO-CHICK, TO SHEW THE STRUCTURE AND RELATIONS OF A LARGE NOTOCHORD. (From Balfour.)

spc, spinal canal; *ch*, notochord within its sheath; *ao*, aorta; *mp*, muscle plate; *vr*, rudiment of vertebral body. The figure is more fully described elsewhere.

as a permanent substitute for the true vertebral column. It is enclosed in a delicate, structureless, or cuticular sheath, outside which in the lower vertebrates, but not in the amniota, another sheath, viz., the elastic, is formed. It is upon the surface of the cuticular sheath in the amniota, and between it and the outer or elastic sheath in the lower vertebrates, that the mesoblastic substance derived from the inner part of the proto-vertebral column is deposited to form the material of the future vertebral bodies in a manner presently to be described. The notochord itself takes no direct part in the formation of the cartilaginous or osseous vertebræ; but its remains are to be found for a considerable time within the bodies of the vertebræ and intervertebral plates, as described by H. Müller (No. 159), and others in the human fœtus to a late period, and even in the child after birth.

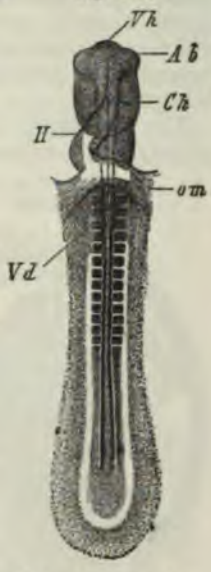
4. **Mesoblastic or Protovertebral Somites.**—There is still another series of early developmental phenomena, which are nearly contemporaneous with the three previously referred to, and which, though not themselves immediately concerned in the production of axial rudiments are yet intimately associated with some of them, and have an important bearing upon the whole after-history of development. Soon after the appearance of the medullary plates and groove, and before the commencement of the closure of the medullary tube, there have appeared on each side of the dorsal ridges a row of well defined, dark, quadrilateral masses, situated in the adjacent column of mesoblast, and separated by clear transverse clefts, or linear intervals.

These masses were for long looked upon as the rudiments of the permanent vertebræ, and were called the *primordial* or *proto-vertebræ*, but they are now known to be of a more comprehensive nature, and receive the appellation of *mesoblastic* or *protovertebral somites*.

In now proceeding to explain the relation of these transversely divided segments to the other phenomena of development, we may

ll the fact, referred to in the account of development in general, the great mass of the mesoblast is very soon divided longitudinally

Fig. 689.



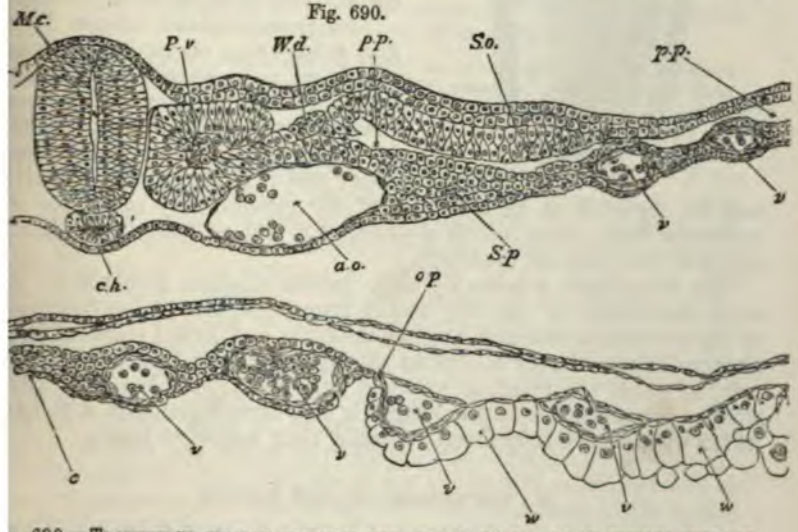
689.—EMBRYO-CHICK AT THE END OF THE SECOND DAY, SEEN FROM BELOW. $\frac{15}{1}$ (From Kölliker.)

, forebrain ; *Ab*, primary ocular vesicles ; *Ch*, notochord ; ubular heart ; *om*, vitelline veins ; *Vd*, entrance to the art of the alimentary canal within the cephalic fold ; in middle part of the embryo, the protovertebral somites are (to the number of thirteen pairs) on each side of the canal e spinal marrow and notochord.

ach side into an inner thick column, in which transverse segmentation into somites more immediately takes place, and which may be therefore ed the *protovertebral columns*, and into flatter *ral plates*, which again very soon become ided horizontally into an upper, or parietal, a lower or visceral lamina, and have between m on each side the *body cavity*, or pleuro-itoneal space. At present we have mainly to with the inner or protovertebral column.

The transverse cleavage of this column, giving e to the protovertebral segments or somites, gins to appear very early at the side of the dorsal ges, near the place where they embrace the imitive streak—a region which the subsequent ndition shows to correspond with that of the terior cervical vertebræ. But as the columns extend backwards, they

Fig. 690.



g. 690.—TRANSVERSE SECTION THROUGH THE DORSAL REGION OF AN EMBRYO CHICK OF 45 HOURS. (From Balfour.)

A, epiblast ; *C*, hypoblast ; *Mc*, medullary canal ; *Pv*, protovertebra or mesoblastic nite ; *Wd*, Wolffian duct ; *So*, parietal mesoblast ; *Sp*, visceral mesoblast ; *pp*, pleuro-itoneal cavity ; *ao*, left primitive aorta ; *v*, blood-vessels ; *w*, germinal wall ; *ch*, tochord ; *op*, place of junction of transparent and opaque areas.

continue to undergo the transverse cleavage, so as to give rise to an increase in the number of the mesoblastic somites; and by the time when the medullary canal is closed, there are as many as ten or twelve of them. This process goes on progressively from the cervical into the dorsal, lumbar, sacral and caudal regions, till a number is attained, which corresponds closely with that of the permanent vertebræ, in which, however, the posterior or caudal segments are comparatively late in being formed.

The mesoblastic segmentation is at first confined to the inner or protovertebral column, and it is most distinct in that part; but in the later development of the walls of the trunk we shall see that a somewhat similar cleavage, or at least a differentiation corresponding with it, extends also into the parietal portion of the lateral mesoblastic plates, so as to give rise in them to the costal and intercostal divisions of the walls.

Fig. 691.

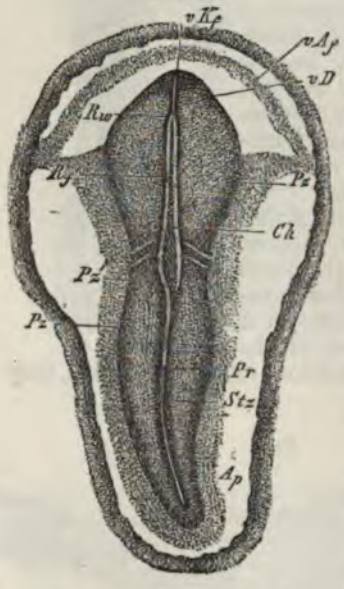


Fig. 691.—Area pellucida and rudiments of the embryo-chick of the second day. ♀ (From Kölliker.)

pr, primitive streak and groove; *Rw*, dorsal or medullary ridges meeting in front; *Rf*, medullary groove; *Stz*, axial zone; *Pz*, parietal zone; *Pz'*, two vertebral somites; *Ch*, notochord; *Vkf*, cephalic fold; *vD*, anterior intestinal fold shining through; *vAf*, anterior or amniotic fold; *Ap*, area pellucida.

The protovertebral column is at first solid, being composed of firmer columnar cells outside, and looser cellular elements internally. Soon, however, the somites become hollow by the liquefaction of the internal cells; and it is held that their cavity may be regarded as an extension of the general body cavity, or the intermesoblastic space, which is so apparent and constant in the lateral plates of the mesoblast (Balfour).

The mesoblastic somites by their further changes give rise to the main constituents of the body wall or framework, that is, the rudiments of the permanent vertebræ, and the muscular and dermal plates. These changes consist mainly at first in the separation of a mesial or internal part, in which the vertebral matrices are formed, from the outer parts which are converted into the muscular and dermal plates in a manner which will be more fully described under their respective heads.

II. FORMATION OF THE TRUNK.

1. **Vertebral Column.**—It is from the inner part of the protovertebral column before mentioned that the blastema of the permanent vertebræ is derived, the rapidly growing cells of which extending inwards and upwards from the protovertebral column, surround the whole of the chorda and the medullary canal with the first, or, as it has been called,

the membranous matrix of the vertebræ previous to their cartilaginous differentiation.

The part of this substance which surrounds the notochord forms at first a uniform or undivided tubular enclosure of the chord; but subsequently it shows transverse divisions corresponding to those of the protovertebral somites. The matrices of the arches, which are continuous with those out of which the bodies are formed, extend dorsally round the medullary canal and between it and the superficial epiblast, so as gradually to enclose the neural canal. These rudimental neural arches are from the first separate or in distinct strips, and thus intervals are left between them for the spinal ganglia and nerves which grow out from the nervous centre.

Fig. 692.

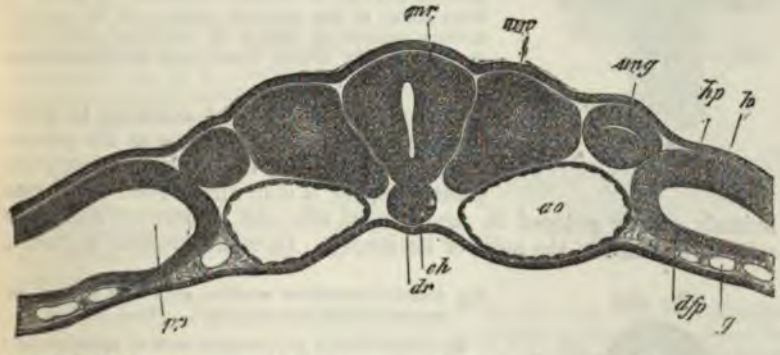


Fig. 692.—Transverse section of an embryo rabbit of 9 days and 2 hours in the middle dorsal region. $\frac{15}{1}$. (From Kölliker.)

mr, medullary tube; *uw*, protovertebral mass; *h*, epiblast; *hp*, parietal mesoblast; *dfp*, visceral division of the mesoblast; *pp*, pleuro-peritoneal cavity between them; *ung*, primitive segmental duct; *g*, vessels in the visceral mesoblast; *ch*, notochord; *dr*, intestinal groove of the hypoblast.

The next step in the formation of the permanent vertebræ is the chondrification or conversion into cartilage of the primitive or membranous matrix. This takes place nearly simultaneously in the bodies and arches, and is found on the fourth day in the chick, and the eleventh or twelfth day in the rabbit, and probably in the fourth and fifth weeks in the human embryo. In the process of chondrification the position of the divisions between the arches remains the same as in the original or protovertebral segmentation; but it is a remarkable fact, discovered by Remak (No. 25), that in the bodies the chondrification is accompanied by a change of such a nature that the separation of the permanent bodies comes to be effected by a new series of clefts, so situated between the former or protovertebral divisions as to cause the permanent intervertebral intervals of the bodies now to fall opposite to the neural arches and muscle plates, and the middle parts of the bodies consequently opposite to the place of the original protovertebral clefts.

While the chondrification of those parts of the vertebral matrices which are to form the bodies is proceeding, a differentiation of the blastema in the interspaces leads to the development of the fibrous substance of the intervertebral discs or ligamentous plates. And here

it is right to mention the changes of form in
coincident with the formation of the parts surr

Fig. 693.

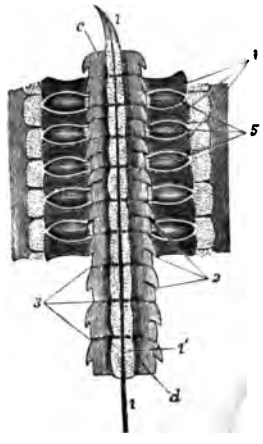


Fig. 693.—CERVICAL PA
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Fig. 69

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; and the subsequent union of these two strips from behi
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later formation. (See Parker, No. 161.) This mode of origin an
elopment of the sternum is interesting in connection with th
formation of fissure or median division of that bone which has be
served in many different gradations.

3. Muscle Plates and Muscles.—The muscles of the trunk derive their origin from the *muscle plates*, which are developed in the upper and outer part of the protovertebral column, in which the primary segmentation of the mesoblastic somites remains quite distinct. When the inner part of the protovertebral column has extended itself into the vertebral matrices of the bodies and arches (as before described), the muscle plates are found to consist of two laminæ, an inner and an outer, between which there is a space which is said to be in communication at first with the body cavity. This space is necessarily subdivided for each muscle plate. As development proceeds, however, the opening into the general body cavity being closed, the outer and inner layers of the plates lie more nearly applied together. The process of conversion into permanent muscular tissue by differentiation of the cells

VERTEBRAL COLUMN

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...epta, and in the higher of tempo-
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...E SECTION THROUGH THE MIDDLE OF AN EMBRYO-CHICK OF THE DAY, WITH OPEN AMNION. ♈. (From Kölliker.)

...mnion consisting of *h*, epiblast, and *ph*, parietal mesoblast; *sk*, lateral ...t and visceral mesoblast; *mp*, muscle-plate; *uwh*, remains of proto-verte-..., *vc*, vena cardinalis; *wg*, segmental duct; *wk*, segmental tube; *p*, peritoneal ...*vp*, visceral mesoblast with vessels; *dd*, hypoblast and intestinal groove.

...dorsal line; they reach also downwards in a ventral direction, and in

Fig. 698.

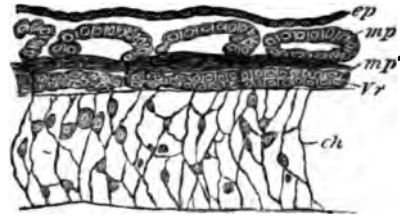


Fig. 698. — HORIZONTAL SECTION THROUGH THE TRUNK OF AN EARLY EMBRYO OF SCYLLIUM, PASSING THROUGH THE NOTOCHORD. (From Balfour.)

ch, notochord; *ep*, epiblast; *vr*, rudiment of vertebral body; *mp*, muscle-plate; *mp'*, portion of muscle-plate already converted into longitudinal muscles.

...part under the vertebral bodies, and they pass into the walls of the ...body externally, and thence ultimately into the limbs.

...Both layers of the muscle-plate are converted into muscles, but while ...it is undoubted that all the voluntary muscles proceed more or less ...directly from the mesoblast and probably from the muscle-plates, it is ...still questioned by some whether the hypaxial as well as the epaxial ...muscles proceed from this source alone.

...In the early stages of muscular development in the amniota the myotomes are ...divided by transverse intermuscular septa, and thus retain much of the character

The history of the further development of the vertebral column belongs rather to that of the ossification of its several parts, which has been described in the first volume. It may be stated in addition here that in the human embryo the process of chondrification of the bodies begins between the fourth and fifth weeks (Kölliker), and is already completed by the sixth or seventh, soon after which ossification commences. In the arches the chondrification is about a week later in commencing, but the ossific deposit, which begins in the eighth week, is slightly earlier in them than in the bodies.

The whole number of cartilaginous vertebral matrices varies from 33 to 35, there being occasional subordinate variations in the number developed in each division of the trunk. The maximum number of coccygeal pieces is six according to E. Rosenberg (No. 166).

The formation of cartilaginous matrices for the vertebral arches begins first in those of the dorsal region, and extends from thence forwards into the cervical vertebræ and basis of the skull, and backwards into the lumbar and sacral vertebræ; but the dorsal extension of the cartilaginous matrix ceases to be formed in the hinder sacral and coccygeal vertebræ where these arches are afterwards deficient.

Rathke first showed (No. 14, ii., 1839) that the body of the Atlas vertebra is merged in the odontoid process of the second or axis vertebra; and that in the tortoise the chorda runs through the odonto-occipital ligament. This was confirmed for mammals by Joh. Müller, and later by Robin and Hasse. According to some the anterior arch of the atlas might belong to the subcentral or hæmal series of arches; but it would appear that the homology of this part is not yet fully determined.

2. **Ribs and Sternum.**—As completing the skeleton of the trunk of the body, it will be convenient to describe here the development of the ribs and sternum.

The ribs are extensions of the vertebral blastema in the thoracic parietal plate of the mesoblast; and their matrices are at first continuous with those of the vertebræ. They undergo early chondrification along with the vertebræ, but become separate from them before ossification commences. At their ventral extremities, as was first shown by Rathke in 1838 (No. 158), the seven which are afterwards to be sternal ribs of each side come to be united together by a longitudinal strip of cartilage; and the subsequent union of these two strips from before backwards gives rise to a single median piece of cartilage, which represents the manubrium and body of the sternum. The xiphoid cartilage is of later formation. (See Parker, No. 161.) This mode of origin and development of the sternum is interesting in connection with the malformation of fissure or median division of that bone which has been observed in many different gradations.

3. **Muscle Plates and Muscles.**—The muscles of the trunk derive their origin from the *muscle plates*, which are developed in the upper and outer part of the protovertebral column, in which the primary segmentation of the mesoblastic somites remains quite distinct. When the inner part of the protovertebral column has extended itself into the vertebral matrices of the bodies and arches (as before described), the muscle plates are found to consist of two laminæ, an inner and an outer, between which there is a space which is said to be in communication at first with the body cavity. This space is necessarily subdivided for each muscle plate. As development proceeds, however, the opening into the general body cavity being closed, the outer and inner layers of the plates lie more nearly applied together. The process of conversion into permanent muscular tissue by differentiation of the cells

has been shown by Balfour to begin first in the inner layer. (See fig. 694 and 698, *mp'*.)

The plates somewhat overlap one another; and connective tissue is deposited in the intervals between them, which in the lower animals is the basis of permanent intermuscular septa, and in the higher of temporary structures of the same kind, and of the perimysial sheaths, &c.

Fig. 697.

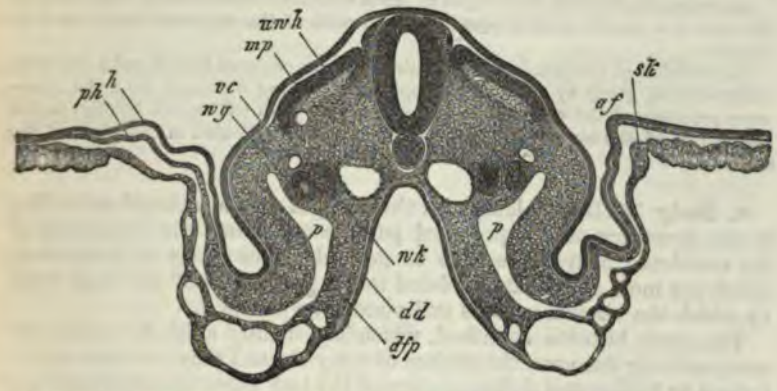


Fig. 697.—Transverse section through the middle of an embryo-chick of the third day, with open amnion. ♀. (From Kölliker.)

af, fold of the amnion consisting of *h*, epiblast, and *ph*, parietal mesoblast; *sk*, lateral fold of hypoblast and visceral mesoblast; *mp*, muscle-plate; *uwh*, remains of proto-vertebral cavity; *vc*, vena cardinalis; *wg*, segmental duct; *wk*, segmental tube; *p*, peritoneal cavity; *dfp*, visceral mesoblast with vessels; *dd*, hypoblast and intestinal groove.

In the progress of growth the muscle-plates extend to near the middle dorsal line; they reach also downwards in a ventral direction, and in

Fig. 698.

Fig. 698. — Horizontal section through the trunk of an early embryo of Scyllium, passing through the notochord. (From Balfour.)

ch, notochord; *ep*, epiblast; *vr*, rudiment of vertebral body; *mp*, muscle-plate; *mp'*, portion of muscle-plate already converted into longitudinal muscles.

part under the vertebral bodies, and they pass into the walls of the body externally, and thence ultimately into the limbs.

Both layers of the muscle-plate are converted into muscles, but while it is undoubted that all the voluntary muscles proceed more or less directly from the mesoblast and probably from the muscle-plates, it is still questioned by some whether the hypaxial as well as the epaxial muscles proceed from this source alone.

In the early stages of muscular development in the amniota the myotomes are divided by transverse intermuscular septa, and thus retain much of the character

of protovertebral segmentation which is familiar as a marked feature of their structure in the lower vertebrates,—a fact of great morphological significance.

The formation of the longer muscles in the higher vertebrates takes place by the disappearance of the intermuscular septa and the longitudinal union of the fasciculi of successive myotomes. In the trunk the direction of these, especially of those most closely attached to the vertebral skeleton, remains for the most part longitudinal, but the more superficial muscles, and especially those connected with the limb-girdles, change their direction as well as their form to a great extent.

According to Balfour, the length of each muscular fibre derived from one of the cells of a muscle-plate is equal to the breadth of the myotome in which it is situated.

The division of the trunk muscles into an upper or dorso-lateral and a lower or ventro-lateral group by a horizontal septum, extending outwards from the transverse processes of the vertebræ and corresponding with that which belongs to the lateral line of the lower vertebrates, is only faintly indicated in the adult of the amniota.

4. **Body Walls.**—Along with the changes now mentioned as leading to the formation of the principal parts constituting the framework of the vertebrate body, there is to be noticed a later series of phenomena which are more immediately related to the production of the outer walls by which the visceral cavities and viscera are enclosed.

The parts hitherto described, which are mainly axial, lie prone and comparatively flat upon the surface of the yolk, and they are also chiefly formed by folding and differentiation of the two upper layers without any direct participation of the hypoblast, which passes thin and flat across the embryonic area below the medullary canal and notochord. But in the further progress of development, and in part simultaneously with the changes already described, the inflection of the peripheral parts of the blastoderm downwards or in a ventral direction, along with their extension and thickening, gives rise to the formation and enclosure of the thoracic, abdominal and pelvic cavities of the trunk.

The first of the folds now referred to, named the cephalic, begins to be formed much earlier than the rest, indeed its rudiment is to be perceived very soon after the appearance of the medullary plates and groove. It involves all the layers of the blastoderm, and is of such a nature as to pass downwards on each side, and gradually progressing backwards, to enclose a space within the layers which, as it is lined by the hypoblast, necessarily comprehends a part of the alimentary canal. This fold also encloses the rudiment of the heart when that organ comes to be formed, extending backwards below the cephalic part of the embryo as far as the fovea cardiaca, and closing in the cephalic part of the alimentary cavity anteriorly by the inflection of the three blastodermic layers below the primitive brain or cranium.

Somewhat later a similar inflection of all the layers occurs at the caudal extremity of the embryo, but this is much shorter than the cephalic fold, and includes therefore a comparatively small portion of the alimentary canal, viz., the caudal and primitive cloacal part, which, like the anterior, is at first completely closed by the inflection of the layers. (See fig. 660.)

Between the cephalic and caudal folds, that is, along the sides of the axial embryo in the greater part of what afterwards becomes the abdominal cavity, the walls of the body also undergo a downward inflection, and as these are continuous before and behind with the cephalic

caudal folds, the place of their meeting, from being at first a wide elongated gap between the cavity enclosed in the embryo and the neral parts of the blastoderm, becomes at last, by the gradual ing of the edges bringing them more and more together, the wer constriction which, from its later relations, is named Umbilical. however, the infolding parts are everywhere composed of the al and visceral plates separated by the body cavity, we have to guish, in the umbilical constriction, the outer wall of the body d of epiblast and parietal mesoblast, from the wall of the alimentary composed of visceral mesoblast and hypoblast.

yond the umbilical constriction the outer or parietal plate is in nuity with the amnion, and the deeper or visceral plate, when the ine assumes a tubular form, is continuous with the yolk sac.

thus appears, as was first shown by Von Baer, as the result of the r changes of vertebrate development, that there are formed two tubular cavities, the one above the other below the notochordal the upper being the cranio-vertebral, enclosing the great nervous e, and the lower being the visceral cavity, in which the alimentary , heart, lungs and other nutritive organs are contained.

ere is not at first any marked distinction between the head and the in the axial part of the embryo, nor is there apparent any neck or cal constriction. The changes which lead to this distinction are of occurrence, and will be considered hereafter in connection with the iption of the development of the head. Here it will suffice to state the cephalic part of the axial body is at first only cranial, and that ace is formed later by the outgrowth of various bars and processes d the sense-capsules, mouth and pharynx, and mainly from the ior and ventral aspects of the cranial part.

ne caudal extremity of the embryo always consists of a prolongation e vertebral column containing the notochord and covered by the epiblast. This extends beyond the place of the primitive caudal and consequently the hinder part of the alimentary canal and organs ected with it fall short of the extremity of the tail.

ne tail of the embryo is the seat of an incurvation which is most nonly ventral, but is sometimes combined with torsion, as is seen remarkable degree in serpents and in various degrees in other animals.

Flexion and Torsion of the Embryo.—Simultaneously with the rrence of the early formative changes before adverted to, there place others which affect the external form and attitude of the

Fig. 699

699.—LONGITUDINAL SECTION THROUGH THE HEAD OF AN EMBRYO OF FOUR WEEKS. (From Kölliker.) ½

anterior encephalic vesicle, cerebral portion; erbrain; *m*, midbrain; *h*, cerebellum; *n*, lla oblongata; *no* and *a*, optic vesicle; *o*, ory depression; *t*, centre of basi-cranial e; *t'*, lateral and hinder parts of tentorium; fold of epiblast which forms the hypo- cerebri.

ryo. These consist mainly of e kinds of flexure and incurva- accompanied by various degrees of growth in the proportions of parts in which they take place. The first may be named the

principal cephalic flexure, and consists in a strong angular flexion of the cranial cavity in a ventral or downward direction in the region of the midbrain and sella turcica of the cranium. The second is, in birds, a more extended curvature of the vertebral column in the region of the neck and thorax, but in mammals more frequently in the lower cervical region only, such as to bend together the head and trunk of the body. The third inflexion is of a different nature from the first two, usually

Fig. 700.

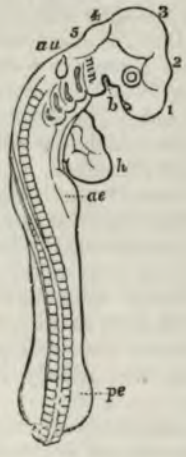


Fig. 700.—OUTLINE OF THE EMBRYO-CHICK AT THE END OF THE THIRD DAY, TO SHOW THE INFLECTIONS OF THE BODY AND THE COMMENCEMENT OF THE LIMBS. (After His.)

1 to 5 the cerebral vesicles; *h*, the mouth; *mn*, the lower jaw, and behind that the branchial bars and clefts; *au*, the auditory vesicle; *h*, the heart; *ae*, anterior extremity; *pe*, posterior extremity; the hinder part of the body is still prone upon the surface of the yolk, the head is now lying on its left side and between is seen the gradual torsion of the vertebral column and trunk.

preceding them in its commencement, and is more marked in birds and reptiles than in mammals; though it also occurs in some of the latter animals. This, as seen in birds, consists in a torsion of the embryo on its axis to the extent of a quarter of a circle, by which, beginning from the head, the embryo, from being at first flat and prone, comes gradually to have the left side lowest and applied to the blastoderm. In rare instances the direction of this torsion is reversed, and the embryo lies on its right side.

This torsion is not so constant in mammals as in birds, and it not unfrequently happens that along with the ventral incurvation of the body, the forepart, notched off from the rest of the blastoderm, sinks deeply into a hollow on the surface of the yolk.

There are, however, many differences in the early attitude of the embryo of mammals in connection with the varieties in the form and size of the yolk sac and other membranes.

III. ORIGIN AND FORMATION OF THE LIMBS.

The limbs arise as outgrowths from the lateral part of the trunk in determinate parts of the thoracic and pelvic regions, and, though not presenting any original protovertebral segmentation, are in some respects to be regarded as lateral extensions of vertebral somites in these situations. They make their first appearance after the completion of the primary steps in the development of the axial structures of the trunk, about the end of the third day in the chick (see fig. 700), and in the third and fourth week in the human embryo. They have the form of semilunar plates of parietal mesoblast covered with epiblast, budding out as it were from the lateral ridge, near the line of separation of the mesoblast into

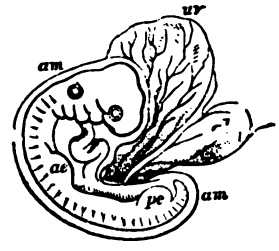
ietal and visceral laminæ, and close to the outer margins of the
-plates.

h limb consists of the supporting arch or girdle, thoracic or pelvic,
is sunk in the substance of the lateral ridge, and makes little or
earance externally, and of the free or projecting part which is at
nite simple, but soon becomes divided into the distal, middle and
al segments.

Fig. 701.

1.—Lateral view of human embryo
ben three and four weeks, to show
ommencing extremities. (A.T.)

the amnion surrounding the embryo;
bilical vesicle; *al*, allantoid pedicle;
rior extremity; *pe*, posterior extremity;
ffian ridge passing between them.



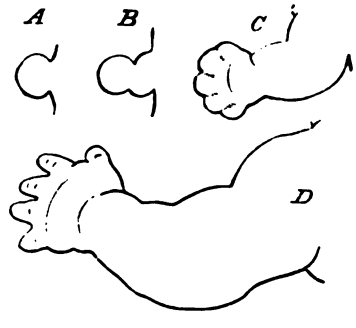
lappet or bud which first shows
ppears to correspond most nearly
he distal segment comprising the
or foot, the other two segments
successively developed between
the root or girdle at an early
. The new part shows itself first
notched separation of a segment between the terminal one and
de of the body, corresponding to the forearm or lower leg, and
followed by the development in a similar manner of the proximal
nt, the upper arm or thigh.

ile these changes in the limbs occur, other advances in form and
ure are discernible, first, in the appearance of four slight notches
free margin of the distal segment, indicating the commencement
pentadactylar division into the elements of fingers or toes, the
tion of which is even more marked by the differentiation of the

Fig. 702.

2.—Outlines of the anterior
emities of human embryoes at
erent ages. (A.T., after His.)

four weeks; *B*, at five weeks;
even weeks; *D*, at nine or ten



substance of the distal
nt; second, in the occur-
of an inflection between
niddle and proximal seg-
, the hollow of which in the
mb looks forward, and in
ind limb backwards with
ace to the axis of the trunk;
ird, in the rapid progress
deeper textural differen-
which leads to the de-
nent of the several components of the limbs, such as the skeletal,
lar, dermal, nervous and vascular parts.

rudimentary limbs consist at first entirely of a mass of nearly

uniform blastemic cells derived from the parietal mesoblast, covered superficially by the cuticular epiblast, which always presents at its extremity a peculiar pointed or conical cap of thickened epidermis. (See fig. 703.)

The development of the parts of the limb now referred to, both in its larger features and in its histological characters, is usually somewhat more in advance in the anterior than in the posterior extremities.

Fig. 703.

Fig. 703.—TRANSVERSE SECTION OF THE BODY OF THE CHICK AT THE LEVEL OF THE ANTERIOR EXTREMITIES. (From Remak.)

am, amnion in its cephalic fold; *ep*, epiblast; *sm*, parietal mesoblast; *vm*, visceral mesoblast; *sp*, spinal marrow; *gn*, spinal ganglion and nerve roots; *mp*, muscle-plate; *dp*, dermal plate; *ch*, notochord, with vertebral matrix round it; *a*, aorta (the two uniting into one); *vc*, cardinal veins; *w*, mesentery and Wolffian bodies; *ae*, anterior extremities composed of mesoblast, *m*, and covered with epiblast thickened at the point; *i*, intestinal canal open below into the yolk sac; *hy*, hypoblast.

Attitude and position of the Limbs.—From the manner in which the primary lappet or limb-plate grows from the side of the axial part of the trunk, it is obvious that at first it must present a dorsal and a ventral surface, corresponding respectively with those of the embryo body, and if we trace the subsequent changes which bring out the features of the later form, we shall find them such as to show that the original dorsal aspect is the extensor and the ventral aspect is the flexor surface of the limb; and further that when the distinction of the subordinate parts begins to be established, the thumb and great toe, reckoned in descriptive anatomy as the first of the series, and corresponding with the radial and tibial borders of their respective limbs, are directed forwards or preaxially, while the fifth toes, with the ulnar and fibular borders of their respective limbs, are directed backwards or postaxially.

As development proceeds, the two primary l
lateral extensions from the trunk, come to
body of the embryo, the anterior with som
with a forward direction. But they h
which the attitude of the distal segm
in this respect, that in the fore-l

middle segments is directed forwards or ventrally, while in the hinder limb it is in the reverse direction, that is backwards or dorsally. In the human body this flexure does not involve any considerable departure from the original relation of the extensor and flexor surfaces to those of the trunk, although in the adult it may appear to do so in consequence of the limb hanging somewhat obliquely in a direction parallel to the main axis of the trunk. But in the hind limb it is obvious that there must be from an early period a certain amount of rotation of the whole limb or from the hip-joint downwards, which brings the extensor surface of the thigh, lower leg and foot forwards, and carries the flexor surface of these parts backwards.

Fig. 704.

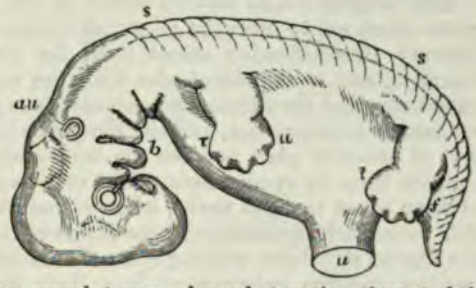


Fig. 704. — DIAGRAMMATIC OUTLINE OF THE PROFILE VIEW OF THE HUMAN EMBRYO OF ABOUT SEVEN WEEKS, TO SHOW THE PRIMITIVE RELATIONS OF THE LIMBS TO THE TRUNK. (Allen Thomson.)

r, the radial (preaxial), and *u*, the ulnar (postaxial), border of the hand and fore-arm; *t*, the tibial (preaxial), and *f*, the fibular (postaxial) border of the foot and lower leg. (The foot is represented at a somewhat more advanced stage than the rest of the embryo.)

In quadrupeds, however, it is different as regards the fore-limb, for in them, while there is the same kind and degree of rotation in the hind-limb, equal to a quarter of a circle, as in man, there is also a rotation of the humerus outwards, and frequently a forward displacement of the upper end of the radius with more or less complete pronation of its lower extremity, which brings the palmar aspect of the fore-limb towards its original ventral position; this becoming most completely restored when in the state of extension more or less of the forefoot supports the body on the ground. In this the pollex, like the hallux, is placed towards the mesial side. This rotation of the fore-limb, amounting in all to half a circle, is made up of an outward rotation of the humerus at the shoulder-joint and an inward rotation of the fore-arm at the elbow-joint.

In the development of the several deeper components of the limbs it is to be observed in the first place with respect to the skeleton, that the formation of the bones with their accessory parts takes place by a primary differentiation of the blastema into cartilaginous matrices and fibrous or membranous parts, and the subsequent calcification of the cartilages and subperiosteal ossification, in the manner fully described in the histological part of this volume (p. 101), to which, as well as to the history of the progress of ossification in the several bones, given in the first volume, the reader is referred.

It may be further stated here that in all the bones of the limbs, with the exception of the terminal phalanges, the processes of cartilaginous calcification and true ossification begin at the middle and extend thence towards the ends of the bone-matrices, but in the terminal phalanges these processes commence in the distal ends and proceed from thence inwards upon the rest of the bone-matrices,—a fact of considerable morphological significance with reference to the determination of the homologies of the terminal elements of the limbs in the lower vertebrates. (Dixey, No. 172.)

It may also be mentioned here that it has been found by Henke and Reyher (No. 165) that in the human embryo of the seventh and eighth weeks there is a distinct cartilage, representing the os centrale of animals, placed between the

scaphoid, magnum and trapezium cartilages, but this central cartilage gradually diminishes and passing dorsally disappears in the course of the third month, without either uniting with any of the neighbouring bone-matrices or undergoing ossification.

Muscles.—With respect to the muscles of the limbs, it seems still doubtful whether they proceed directly from the muscle-plates, which it is admitted reach the root of the limbs by their outer edge, or whether they arise locally. It may be that the muscles take their origin in both of these modes, the trunk-muscles which are attached to the limbs being most probably formed in connection with the muscle-plates.

The Joints.—The differentiation of the blastemic tissues into the parts which are to form the joints takes place at the same time that the primary chondrification shows itself for the formation of the bone-matrices, and is coincident also with the commencement of the perichondrium and the fibrous and vascular osteogenic elements. There are at first no joint-cavities, and the fibrous or connective tissue, forming a sort of articular plate between the bone-matrices, may therefore be said to unite them by syndesmosis. But very soon, or in the human embryo of from seven to eight weeks, when chondrification is complete, narrow slits make their appearance in the places of the future joint-cavities, and the fibrous structures retiring from the interior towards the surface, the cavities undergo enlargement into their permanent form,—a process which approaches completion in the human embryo of four months.

The ligaments are developed from the remains of the fibrous matrix, in connection with the earlier perichondrium which becomes converted afterwards into permanent periosteum.

Nerves and Blood-vessels.—The nerves of the limbs probably differ from their other constituents as regards their origin, in this respect, that they are prolonged into the limbs by extension from the nerve-roots which emanate from the spinal marrow. Similarly the blood-vessels of the limbs arise to some extent by prolongation from those of the trunk ; but no doubt there are also many blood-vessels formed locally or within the mesoblastic tissue of the limbs ; and it is not known to what extent the growth of the nerves in the peripheral parts of the trunk and limbs may be due to a similar local development.

IV. EXTERNAL COVERING OF THE BODY AND LIMBS.

The epiblast which is not employed in the formation of the nervous centre or other deeper parts remains as the source of the epidermis and its appendages. This covers all the external surface of the body and penetrates into such cavities as the mouth and nasal fossæ, &c., whose surfaces are in original continuity with it. Besides the two layers distinguished as corneous and mucous in the epidermis, it gives rise to the hairs and nails, and the teeth of mammals, to the feathers of birds and to the scales and horny plates of these or other animals. It is, however, closely united with the subjacent dermoid tissue, from the blood-vessels of which the materials for its formation and that of its appendages are derived.

The true skin or dermis, of a much more complex structure, is formed entirely from mesoblast, and arises in close connection with the muscular plates The fasciæ and connective tissues spring from the same source.

The cellular str oriferous glands, and

also of the mammæ, is all of true epiblastic origin; but their blood-vessels, connective tissue, and other superadded parts are derived from mesoblast.

V. FORMATION OF THE HEAD.

The distinction between the head and trunk by the formation of a cervical constriction is a change of comparatively late occurrence, but even long before this constriction appears, the characteristic features of the parts in these three regions have become apparent. The head may be said to consist at first wholly of the cranial part,—the face being developed at a later period from a series of outgrowths or bars which proceed downwards and forwards from the base and front part of the cranium. The head in its primitive cranial form is, of course, covered externally like the rest of the body by the epidermis derived from the epiblast, and between this and the primary medullary wall of the great nervous centre a layer of mesoblast is soon interposed, from which originate the cover-

A Fig. 705. B

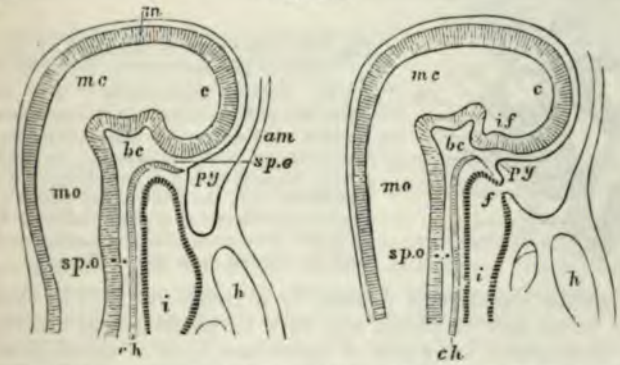


Fig. 705.—VERTICAL SECTION OF THE HEAD IN EARLY EMBRYOES OF THE RABBIT. Magnified. (From Mihalkovics.)

A. From an embryo of five millimetres long.
B. From an embryo of six millimetres long.
In A, the faucial opening is still closed; in B, it is formed; *c*, anterior cerebral vesicle; *mc*, meso-cerebrum; *mo*, medulla oblongata; *m*, medullary layer; *if*, infundibulum; *am*, amnion; *spe*, spheno-ethmoidal, *bc*, central (dorsum sellæ), and *spo*, spheno-occipital parts of the basis cranii; *h*, heart; *f*, anterior extremity of primitive alimentary canal and opening (later) of the fauces; *i*, cephalic portion of primitive intestine; *ch*, notochord; *py*, buccal and pituitary involution.

ings of the brain, the muscular plates, the cartilaginous and bony elements, the true skin, the connective tissue, blood-vessels, and other components of the more advanced cranial walls. This mesoblast may be regarded as a cephalic prolongation of the protovertebral plates of the trunk, but as we shall see hereafter without undergoing obvious metameric segmentation.

The notochord, as already stated, extends for some distance into the the cranium, and is there imbedded in a mass of tissue, the *in-* of Rathke, which afterwards becomes the *parachordal* car- the principal matrix of the future bony walls of the ar forward as the sella turcica. From this place the

cartilaginous rudiments are continued forwards in two more or less united bars named the *trabeculæ cranii* by Rathke, and having a space between them posteriorly which is afterwards the seat of the pituitary gland. The trabeculæ stretch forward until they reach the region of the olfactory pits, and enclose that depression on each side with the nasal cartilages developed from them in front.

The basis cranii in this view may be considered as composed of a posterior chordal part the *occipito-sphenoid*, and an anterior achordal part the *spheno-ethmoid*.

The facial part of the head, on the other hand, is mainly composed of plates or bar-like growths from the front and sides of the base of the cranium which may be distinguished as of two sets, according as they are placed in front of or behind the mouth or buccal cavity. But the mouth as we know it at a later period, either in the form of a cavity of the face or as the anterior aperture of the alimentary canal, has at first no existence, the anterior extremity of that canal being closed by the original cephalic fold of the blastoderm, and the forehead, nose, cheeks, jaws and lips being as yet entirely absent.

Fig. 706.

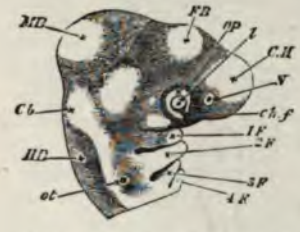


Fig. 706.—SIDE VIEW OF THE HEAD OF AN EMBRYO-CHICK OF THE THIRD DAY. (From Balfour.)

CH, cerebral hemispheres; *FB*, thalamencephalon; *MB*, midbrain; *Cb*, cerebellum; *HB*, medulla oblongatæ; *N*, nasal pit; *ot*, auditory vesicle not yet closed externally; *op*, optic vesicle, with *l*, the lens, and *chf*, the choroidal fissure (in mesoblast); 1*F*, the first visceral fold or plate, the superior maxillary fold slightly indicated above it; 2, 3, 4*F*, the second, third and fourth visceral plates with the visceral clefts between them.

The mouth therefore is formed by a transverse cleft or depression between facial bars or plates, and owes its production as a cavity more to the development outwards of these bars, than to the depression inwards of the anterior cranial wall in which it is situated. The later formed buccal aperture or communication with the pharynx is produced only on the fifth day in the chick by a wearing through or absorption of the epiblast and hypoblast of the original cephalic fold at the fauces or anterior part of the primitive alimentary cavity. The facial plates which are in front of the future mouth, and are sometimes named *preoral arches*, consist mainly of the single or median fronto-nasal plate, and in lateral pairs of the external nasal and maxillary plates, the last constituting the basis of the upper jaw, and arising in connection with the mandibular next mentioned.

The subcranial plates or bars which lie behind the mouth, and are, therefore, named *postoral arches*, consist in the amniota of five pairs of wall plates, meeting each other ventrally below the mouth and pharynx. The first of these, named mandibular, is that in which the lower jaw is formed. The second pair of bars is the seat of development of the upper part of the hyoid bone, and is therefore named hyoid. The three following bars correspond in their relations with the most anterior of the arches which support the developed gills of aquatic vertebrates, and may therefore be strictly named branchial,—a name which was not inappropriately given to the whole series by their discoverer, Rathke.

The skull like the rest of the skeleton is at first entirely membranous;

chondrification then takes place in certain parts of the blastema; and ossification follows in the third stage, partly in the cartilaginous and partly in the membranous matrices.

1. **The Cranium.**—The basal portion of the cranium, as already stated, consists primarily of two fundamental parts. Of these the posterior is distinguished, as before stated, by the presence of the prolongation of the notochord within it as far forward as the part of the skull which afterwards becomes the dorsum sellæ. This portion, comprehending the parachordal plates which surround the anterior extremity

Fig. 707.—THE LOWER OR CARTILAGINOUS PART OF THE CRANIUM OF A CHICK OF THE SIXTH DAY. (From Huxley.)

1, 1, chorda dorsalis; 2, the shaded portion here and forwards is the cartilage of the base of the skull; at 2, the occipital part; at 3 the prolongations of cartilage into the anterior part of the skull called *trabeculæ cranii*; 4, the pituitary space; 5, parts of the labyrinth.

Fig. 707.

of the notochord, contains the matrix of the future basi-occipital and basi-sphenoid cartilages. By its later extension to the sides, it forms the matrix of the exoccipitals and the periotic mass of cartilage which surrounds the primary auditory vesicles. The main part extends forward below the posterior and middle primary encephalic vesicles, ending at the pituitary fossa.

The *spheno-ethmoid* portion of the basis cranii contains the matrix of the presphenoid, and the septal-ethmoid cartilages. It is mainly produced in connection with the trabeculæ cranii, which are in direct continuity with the anterior part of the parachordals.

The trabecular part lies below the anterior encephalic vesicle, and becomes greatly modified in connection with the expansion of the cerebral hemispheres and the development of the nasal fossæ and mouth, together with the other parts of the face.

The three principal sense organs, it may here be stated, the nose, eye, and ear, formed in connection with their several primary nervous parts derived respectively from the cerebral hemispheres, the thalamencephalon, and the third primary vesicle, are interposed between the rudimentary parts of the head as follows, viz.: the nose between the frontal, ethmoid and maxillary; the eye between the frontal, sphenoid, ethmoid and maxillary; and the ear between the basi-occipital, exoccipital and alisphenoid. Of these the auditory vesicles come to be surrounded by a thick cartilaginous wall which is continuous with the parachordal cartilage and seems to take the place of that cartilage as a part of the general cranial wall.

While the base of the cranium, to the extent already mentioned, is cartilaginous in its origin, the lateral and upper walls are chiefly of membranous formation, as in the squama occipitis, the squamo-zygomatic of the temporal, the parietal and the frontal bones.

The membranous tissue in which these flat bones of the cranial vault are formed is regarded by Kölliker as of dermal origin, and the bones as belonging to the group of investing bones. Their formation is however

in part supplemented by the extension upon them from below of a plate of cartilage which is placed internally to the membranous matrix.

The trabeculæ stretch forward to the anterior extremity of the head, and maintain the foremost place in the seat of the nasal cartilages and external apertures of the nose. Behind these the coalesced trabeculæ

Fig. 708.

Fig. 708.—VIEW FROM BELOW OF THE CARTILAGINOUS BASE OF THE CRANIUM WITH ITS OSSIVIC CENTRES IN A HUMAN FŒTUS OF ABOUT FOUR MONTHS. (From Huxley, slightly altered.)

The bone is dotted to distinguish it from the cartilage, which is shaded with lines. 1, the basilar part, 2, the condyloid or lateral parts, and 3, 4, the tabular or superior part of the occipital surrounding the foramen magnum; 5, centres of the presphenoid on the inside of the optic foramen; 6, centres of the post-sphenoid; 7, centres of the lesser wings or orbito-sphenoid; 8, septal cartilage of the nose; 9 and 10, parts of the labyrinth.

form a narrow ethmo-vomerine cartilage, the nasal septum, round the back of which the vomer is formed as a bony splent covering; while in the hinder lyre-shaped interval of the separated trabeculæ is placed the infundibulum in connection with the pituitary body.

From the side of the presphenoid cartilage the matrix of the orbito-sphenoids or lesser wings, containing the optic foramina, is developed: and from the sides of the basi-sphenoid proceeds the matrix of the greater wings, which are also cartilaginous in their origin.

In the periotic or cartilaginous rudiment of the temporal bone three centres of formation are distinguished by Huxley, viz.: 1. *Opisthotic*, or that surrounding the fenestra rotunda and cochlea; 2, *prootic*, or that which encloses the superior semicircular canal; and 3, *epiotic*, or that

Fig. 709.

Fig. 709.—BASILAR PART OF THE PRIMORDIAL CRANIUM OF A HUMAN FŒTUS OF THREE MONTHS, SEEN FROM ABOVE. (From Kölliker.)

a, upper half of the squama occipitis; *b*, lower half of the same; *c*, cartilaginous plate extending into it; *d*, (in the foramen magnum) the exoccipital; *e*, basi-occipital; *f*, petrous, with the meatus auditorius internus; *g*, dorsum sellæ, with two nuclei belonging to the basi-sphenoid bone; *h*, nuclei in the anterior clinoid processes; *i*, great wing nearly entirely ossified; *k*, small wings; *l*, crista galli; *m*, cribrethmoid; *n*, cartilaginous nose; *o*, strip of cartilage between the sphenoid and the parietal; *p*, osseous plate between the lesser wings and the cribriform plate.

which surrounds the posterior semicircular canal and extends into the mastoid portion. They soon unite into one so as to form the petro-mastoid bone.

Here it may be stated that, in addition to the parts of the skull before-mentioned, the ethmo-turbinals and cribriform plate, the styloid process and the three auditory ossicles are of cartilaginous origin; but the

tympanic ring, the nasal, maxillary and other facial bones are all formed in membrane. To these, however, we shall recur hereafter.

In the cranium of the human embryo chondrification begins in the basilar portion in the fourth and fifth weeks, and is nearly completed for the principal parts by the eighth week, soon after which in the course of the tenth week cartilaginous ossification sets in. But in some of the membrane bones, as for example in the lower jaw, ossification begins at a much earlier date, probably in the sixth week.

The form of the head is greatly modified at an early period of development by the cranial flexure as well as by the changes which accompany the development of new parts.

The Cranial Flexures.—The earliest and the most important of the cranial flexures is that, previously mentioned, which takes place at the anterior extremity of the notochord and in the region of the mid-brain or middle encephalic vesicle. At this place the medullary tube, and the substance forming the wall of the cranium especially, undergo a sudden bending downwards and forwards, so as to cause the projection of the thickened cranial base in a marked manner upwards. This coincides with the place where the parachordals and the trabeculæ meet, and where inferiorly the pituitary body, and superiorly the infundibulum come into close relation.

Fig. 710.—Longitudinal section through the head of an embryo of four weeks. (From Kölliker.) $\frac{10}{1}$.

v, anterior encephalic vesicle, cerebral portion; *z*, inter-brain; *m*, mid-brain; *h*, cerebellum; *n*, medulla oblongata; *no* and *a*, optic vesicle; *o*, auditory depression; *t*, centre of basi-cranial flexure; *t'*, lateral and hinder parts of tentorium; *p*, the fold of epiblast which forms the hypophysis cerebri.

Fig. 710.

Above and behind this, the mid-brain gives greatest prominence to the part of the cranium occupied by it, a feature which remains characteristic of the embryo head for a considerable time.

The great cranial flexure thus marks the division between the strictly basi-cranial, or occipito-sphenoidal, and the basi-facial, or spheno-ethmoidal part, the chorda terminating between those two portions of the cranial base, with a thinner pointed part. Here the end of the chorda is bent downwards and forwards, and terminates in the post-sphenoid body, at the dorsum sellæ.

Other flexures also occur in connection with the development of the brain, but these do not affect materially the external form of the head. In man and the higher mammals the greatest modification of that form results primarily from the expansion of the cerebral hemispheres, and secondarily from the formation and proportional increase in the size of the jaws and other parts of the face.

1. **The Face.**—The formation of the facial part of the head takes place superficially by the downward and forward growth from the front and base of the simple cranium of the median *fronto-nasal* and the lateral *maxillary and mandibular* plates, and more deeply by the development of parts in connection with the cranio-facial axis, which is formed by the spheno-ethmoid extension of the trabeculæ

cranii. These formative changes are of a very complex kind, and comprehend the production of the external nose, the lips and cheeks, the jaws and palate, the deeper nasal fossæ and their labyrinth, the buccal cavity and the orbits, the auricle, auditory meatus and tympano-Eustachian passages, together with the various cavities of the bones in communication with the involuted nasal passages, such as the ethmoid, maxillary, sphenoid and frontal sinuses.

These parts all arise mainly in mesoblastic tissue, but are covered externally by epiblast, or are lined internally by that layer, excepting the tympano-Eustachian passage, which has a hypoblastic lining. The basi-facial axis is at first necessarily very short, as it lies only below the undeveloped first cerebral vesicle, but it speedily assumes greater proportions as it is elongated forward with the enlargement of the cerebral hemispheres and the simultaneous development of the nasal and buccal fossæ.

The nasal fossæ take their origin in the form of two simple depressions, the *primary olfactory* or *nasal pits*, which appear on the lower

Fig. 711.

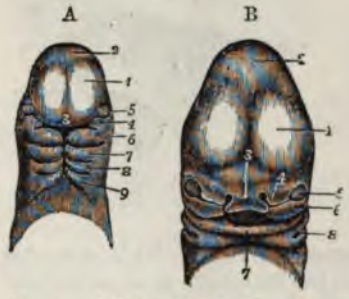


Fig. 711.—Cranium and face of the human embryo, seen from before. (From Ecker.)

A, from an embryo of about three weeks: 1, anterior cerebral vesicles and cerebral hemispheres; 2, inter-brain; 3, middle or fronto-nasal process; 4, superior maxillary plate; 5, the eye; 6, inferior maxillary or mandibular plate (first postoral); 7, second plate; 8, third; 9, fourth, and behind each of these four plates their respective pharyngeal clefts. B, from an embryo of five weeks: 1, 2, 3, and 5, the same as in A; 4, the external nasal or lateral frontal process; 6, the superior maxillary plate; 7, the mandibular; ×, the tongue; 8, the first pharyngeal cleft, which becomes the auditory passage.

surface of the wall of the anterior cerebral vesicle at a very early period when no other parts of the face have yet been formed. But the trabecular part of the cranial wall, now extending forwards and doubling itself at its anterior extremity, curves round both the nasal pits from the inside and above, so as to cover them in some sort with a dome (Parker), in connection with which are afterwards formed the forepart of the septum and the lateral nasal cartilages. The nasal pits have at first no connection with the mouth, which forms a transverse depression in the lower and hinder part of the future face; but later, or by the fifth week in the human embryo, these cavities are brought into communication by the formation of the nasal grooves which run backwards one from each olfactory pit into the mouth, and at the same time the nasal fossæ begin to extend themselves upwards as narrow passages on each side of the enlarging septum, the lower part of the fossæ being still left in open communication with the buccal cavity.

Fronto-nasal Plate.—The external nose owes its origin to the development of the fronto-nasal plate, previously mentioned, which forms a broad median lappet in the fifth and sixth weeks of the human embryo, descending from the front of the cranium between the two large ocular vesicles as far as the transverse buccal cleft. It is free in front and inferiorly, but behind it is in union with the parts developed from

the trabecular axis. Its lower border encloses the nasal pits which come to form deep notches in it, and it is thus divided into a median and two lateral nasal processes. The central division forms the prominent part of the future nose with its *columella* below, and its further prolongation downwards gives rise to the *lunula* or central part of the upper lip; while the parts outside the nasal notches, *the external nasal processes*, receding somewhat, reach the orbital fissure, and are the source, later, of the alæ of the nose.

The further development of the nose consists mainly in the formation of the deeper parts, such as the septum, cribriform plates, and the labyrinth or turbinal portions, which will be noticed in connection with the olfactory organ. Here we have only to do with its relation to the face and mouth.

The Mouth.—The buccal cavity arises as a wide cleft or depression in the lower part of the face, having above it the fronto-nasal process in the middle, and the superior maxillary processes on each side, and

Fig. 712.

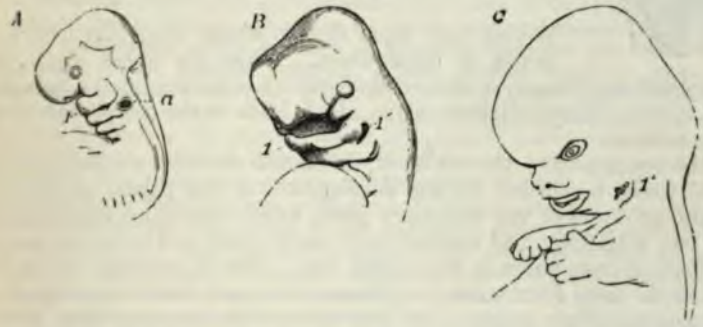


Fig. 712.—Outlines showing the early changes in the form of the head of the human embryo.

A, profile view of the head and fore part of the body of an embryo of about four weeks (from nature, $\frac{10}{1}$): *a*, the auditory vesicle; 1, mandibular arch, and behind this are seen the three following arches with the corresponding pharyngeal clefts. *B*, embryo of about six weeks (from Ecker, $\frac{5}{1}$); 1, the lower jaw: 1′, the first pharyngeal cleft, now widening at the dorsal end, where it forms the meatus externus; the second cleft is still visible, but the third and fourth clefts are closed and the corresponding plates have nearly disappeared. *C*, from a human fœtus of nine weeks (from nature, $\frac{2}{1}$); the features of the face are now roughly formed; the meatus is forming in the dorsal end of the first pharyngeal cleft, and the auricle is beginning to rise from its outer border.

below it the first pair of visceral arches or mandibular plates, which meet each other in the middle, and are continuous round the outer angles of the mouth with the maxillary processes; the deepening of the buccal cavity itself being mainly due to the outward development of these several processes.

The primitive mouth (*stomodæum*) is therefore lined entirely by epiblast, and is separated from the fore-end of the pharynx by this layer, as well as by the inflection of the visceral mesoblast and the hypoblast which close that cavity anteriorly. The establishment of a communication between the mouth and pharynx by the wearing through of the several blastodermic layers named, in the form at first of a vertical slit,

takes place on the fifth day in the chick, and probably at the eighth or ninth week in the human embryo. To this change, which gives rise to the aperture of the fauces, reference will again be made in the history of the development of the alimentary canal. From what has been said previously, it is apparent that the upper lip is formed in part by the fronto-nasal and maxillary plates which are at first separated by the orbital fissures, and that the lower lip is a part of the mandibular plates. The integrity of the upper lip is established by the inward advance of the superficial part of the lateral maxillary processes, which, coalescing with both the internal and external nasal processes, close in the nasal notches inferiorly as the nostrils, and obliterate in great part the orbital fissures,

Fig. 713.

Fig. 713.—HEAD OF HUMAN EMBRYO OF EIGHT WEEKS, SEEN FROM BELOW, THE LOWER JAW HAVING BEEN REMOVED. (From Kölliker.)

n, the external nasal apertures; *i*, premaxillary process, and outside this the internal nasal aperture; *m*, palatal process advancing from the side to form the partition between mouth and nose; *p*, common cavity of the nose, mouth and pharynx.

leaving only more deeply within them the lachrymal canals or nasal ducts. While the upper lip is thus completed superficially, a deeper development and union of the maxillary and intermaxillary matrices occurs, which leads to the completion of the alveolar arch.

The separation of the cavity of the mouth strictly so called from the nasal fossæ, is effected by the development of the palatal or ptergo-palatal processes of the maxillary plate, which advancing inwards from the two sides meet and coalesce with each other and with the septum descending from above in the middle line. But this median union does not in the same form extend to the anterior part which is occupied by the intermaxillary process; for here the maxillo-intermaxillary cleft is double, and, when the union of the opposite parts takes place, the naso-palatine canal is left as the vestige of the previous fissures.

Fig. 714.

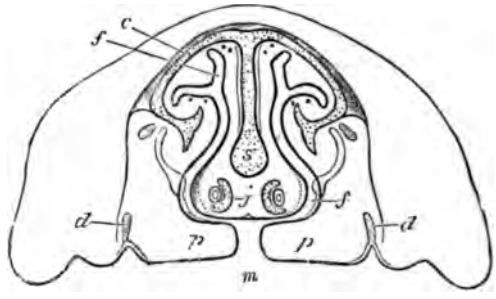


Fig. 714.—OUTLINE OF A TRANSVERSE VERTICAL SECTION THROUGH THE NOSE AND UPPER JAW OF A SHEEP'S EMBRYO WITH OPEN PALATE. (From Kölliker, slightly magnified.

The lower jaw and tongue are removed: *m*, the mouth; *d*, dental germs; *p*, the palate plates approaching each other in the middle; *f*, the nasal fossæ; *c*, nasal cartilages; *s*, septal cartilage; *j*, the two organs of Jacobson with their cartilages internally.

The median union of the palate begins in front about the eighth week in the human embryo, and reaches the back part, when completed, in the ninth and tenth weeks. There are thus formed the hard and soft palates as the floor of the lower or respiratory part of the nasal fossæ,

leading posteriorly into the pharynx, and the roof of the proper buccal cavity. The malformations of double hare-lip and maxillo-intermaxillary clefts, which usually accompany it on one or both sides, together with that of the single or median cleft palate in its various degrees, receive an interesting explanation from the study of the developmental phenomena now referred to.

It is in connection with the lower part of the septum and intermaxillary plate that there are found at an early period in the human embryo as well as in that of other mammals the rudiments of the **Organ of Jacobson** and the inferior internal nasal cartilages which surround them externally (see fig. 714).

It may further be mentioned at this place that from the roof of the mouth at a very early period, as by the third or fourth week in the human embryo, there is formed the diverticulum lined by epiblast, which in its combination with the infundibulum and farther development, gives rise to the pituitary body (see later, p. 831).

In the superficial part of the maxillary plates are formed the superior maxillary and malar as membrane or investing bones, and on the inside of the orbit in connection with the nasal duct the lachrymal bones.

There is a marked difference between the bones which arise in connection with the trabeculæ, such as the pre-sphenoid, orbito-sphenoid, septal ethmoid, cribriform and ethmo-turbinal, which have all cartilaginous matrices, and those which are of membranous origin and have an investing character, such as the nasal, lachrymal, vomer, internal pterygoid, palatal, superior maxillary, malar and mandibular bones of the face. It is, however, an interesting fact (Kölliker) that the various sinuses which come to occupy places within some of the cranial and facial bones, such as the ethmoid, maxillary, sphenoid and frontal, all arise by extension of the epiblastic lining of the nasal passages, and are preceded by the formation of cartilaginous capsules, within each of which the epiblastic extension is situated, and that these epiblastic and cartilaginous capsules make their way gradually into the interior of the respective bones afterwards occupied by the sinuses, the bones being gradually hollowed out by absorption to receive them. In this process the ethmoid sinuses are the earliest to be formed, beginning at the sixth month in the human embryo ; the maxillary follow very soon, or nearly at the same stage, but continue to grow for a long time. The sinuses do not penetrate the sphenoid till about the seventh year, having peculiar relations with the bones of Bertin (see vol. I., p. 72), and the frontal sinuses are the latest in appearing, not having made much progress till the age of puberty, when they expand rapidly, and when also all the others undergo a greater extension.

2. **Postoral Visceral Arches—Branchial Arches.**—The formation of the lateral and lower parts of the face, including the mouth and lower jaws, the hyoid apparatus, the auricles and tympano-Eustachian passages, is intimately connected with the development of the subcranial pairs of processes which are most appropriately named the *Visceral Arches*, as enclosing the mouth and the anterior or pharyngeal portion of the primary alimentary cavity. The visceral arches now referred to were first described by Rathke in 1825, (No. 173,) and from their general homology with the arches of the gills in aquatic animals were named by him the branchial arches. Their development was subsequently very fully investigated by Reichert (1837, No. 174).

In the amniota the postoral visceral arches are four, or, according to some, five in number. The first or anterior of these plates, which forms the posterior margin of the mouth, and is named *mandibular*, is the seat of formation of the lower jaw ; the second, named *hyoid*, gives origin in part to the hyoid apparatus ; the third arch, in which the remainder of the hyoid bone is formed, and which may be named *thyro-hyoid*, corresponds to

the first of those which in aquatic animals undergoes full branchial development, but which in the amniota, like the two following it, never bears gills.

The fourth and fifth arches have no special names, but might be termed post-hyoid or cervical, as being situated in the place where the elongation of the neck occurs at a later period,—a process which gives rise to some of the peculiar features familiar to anatomists as characterising the parts occupying the cervical region.

Visceral Clefts.—Behind each of these visceral arches there is placed on each side a cleft which runs through the wall of the body from the external surface into the cavity of the pharynx, thus bringing epiblast and hypoblast into continuity. The first of these clefts, which from its position may be named *hyo-mandibular*, is afterwards the seat of the formation of the Eustachian passage and cavity of the tympanum

Fig. 715.

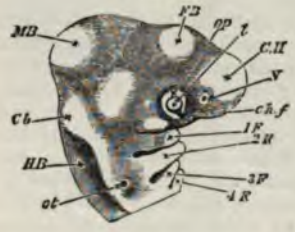


Fig. 715.—SIDE VIEW OF THE HEAD OF AN EMBRYO-CHICK OF THE THIRD DAY. (From Balfour.)

CH, cerebral hemispheres; *FB*, vesicle of the third ventricle; *MB*, mid-brain; *Cb*, cerebellum; *HB*, medulla oblongata; *N*, nasal pit; *ot*, auditory vesicle not yet closed externally; *op*, optic vesicle, with *l*, the lens, and *ch.f*, the orbital fissure (in mesoblast); *1F*, the first visceral fold or plate, the superior maxillary fold slightly indicated above it; 2, 3, *4F*, the second, third, and fourth visceral plates with the visceral clefts between them.

internally, while the meatus auditorius is developed externally round the dorsal part of the cleft by the outgrowth of the neighbouring parts of the two arches; the membrana tympani growing up between them. The external auricle is developed from the integument behind the meatus. The three remaining clefts, which represent branchial apertures of aquatic animals, are all closed in the amniota at an early period, corresponding to the sixth or seventh week in the human embryo.

In some of the lower vertebrates, as in the elasmobranchs and cyclostomes, the hinder branchial arches are more numerous than in other animals, and in some the hyoid arch possesses a developed gill. In aquatic animals generally the gill arches have cartilaginous bars, but in man and mammals it is only in the three first visceral arches, that is, the mandibular, hyoid and thyro-hyoid, that cartilaginous bars are formed.

Through each of the visceral arches there runs a considerable arterial vessel, which is one of the five pairs of vascular arches formed by the division of the aortic bulb, and which in the embryoes of amniota reunite dorsally, without subdivision into branchial vessels, to form the aorta (see Vascular System, p. 868).

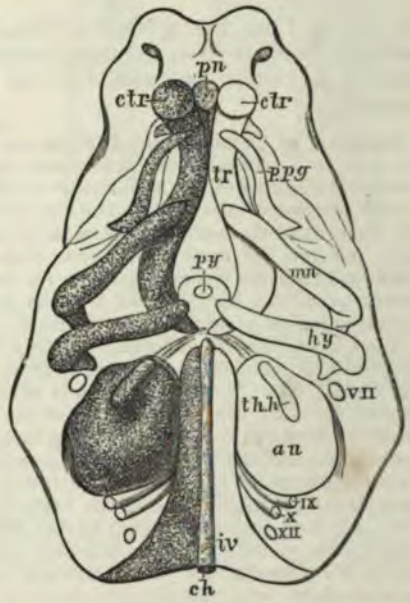
It is an interesting fact stated by Balfour that in the early stages of development of the branchial plates in elasmobranchs there is in the outer part of each of them a cavity extending from the ventral to the dorsal ends, which he regards as having been derived by extension from the general body-cavity in the same manner as occurs in the vertebral somites of the trunk of the body; and further that muscle-plates are formed round these head cavities, which probably furnish the rudiments of a certain number of the head muscles.

Farther Destination of the Visceral Arches.—Some of the remaining facts respecting the development of the visceral arches will be most conveniently described along with those relating to the formation of

ear and other organs with which they are associated. Here it will sufficient to state shortly the principal destination of each of n,

he cartilage of the first or mandibular visceral arch has long been wn as the *cartilage of Meckel*, which occupies the deeper part of the from a very early period, and, attaining considerable size, remains le in the human fœtus up to the sixth or seventh month. Its imal portion is now known to be converted into the *malleus* of mmals, and into the homologous *quadrate* bone of reptiles and birds. n mammals the lower jaw, corresponding mainly with the dentary e of other animals, is developed at a very early period first from

Fig. 716.



716.—PLAN OF THE SKULL, &c., OF THE EMBRYO PIG, SEEN FROM BELOW. Magnified ten diameters. (From Parker.)

cartilage of the trabeculæ; *ctr*, a trabecularum; *pn*, prenasal lage; *ppg*, pterygo-palatine car- e; *mn*, the mandibular arch Meckel's cartilage; *au*, the tory vesicle; *hy*, the cerato- l arch; *thh*, the thyro-hyoid; the pituitary fossa; *ch*, the chord in the cranial basis, sur- ded by the parachordals (*iv*); facial nerve; IX, glosso-pharyn- ; X, pneumogastric; XII, hypo- al nerve.

nbrane outside Meckel's car- ge; but it is also partially rporated with those car- ges at their lower or distal where they meet each other he symphysis. A part of ckel's Cartilage between the and the malleus is con- ed into the so-called in- al lateral ligament of the .

The second or hyoid visceral arch is originally closely united with first arch at its cranial extremity below the auditory capsule. It tains in its proximal part the cartilaginous matrix of the incus, ich becomes articulated with the head of the malleus formed in the jacent proximal part of the mandibular arch. The remainder of this tilaginous bar forms the tympano-hyal and styloid processes, the stylo- oid ligament, and the lesser wings of the hyoid bone (cerato-hyal).

The third visceral arch or thyro-hyoid gives rise, by its cartilaginous trix, to the great wings and body of the hyoid bone. It supports the diment of the thyroid cartilage, and is closely connected with the velopment of the larynx.

The fourth and fifth arches, as already remarked, may be considered belonging to the neck rather than to the head. The congenital sures of the neck which have been observed as a malformation, and ich usually open externally far down in that region, may be due to

the persistence of one or more of the branchial clefts, much drawn out by the cervical elongation.

The tongue is formed, according to Kölliker, in connection with the three first visceral arches, but mainly with the mandibular. Its covering

Fig. 717.

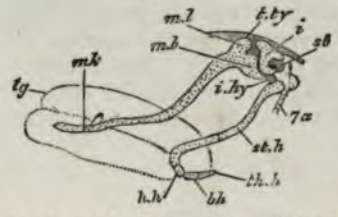


Fig. 717.—SIDE VIEW OF THE MANDIBULAR AND HYOID ARCHES IN AN EMBRYO PIG OF 1½ INCH IN LENGTH. (From Balfour, after Parker.)

tg, tongue ; *mk*, Meckel's cartilage ; *ml*, body of malleus ; *mb*, its manubrium or handle ; *t.ty*, tegmen tympani ; *i*, incus ; *st*, stapes ; *i.hy*, inter-hyal ligament ; *st.h*, stylo-hyal cartilage ; *h.h*, hypohyal ; *bh*, basibranchial ; *th.h*, rudiment of first branchial arch ; *7a*, facial nerve. See also fig. 745, p. 839.

is derived from the epiblast of the mouth, its muscular substance probably proceeds from the muscle-plates of the visceral arches, and it rests by its base on the mesial process of the third arch, the basihyoid element.

Relation of Developmental Facts to the Morphology of the Head.—It may be freely admitted that there is no primary segmentation of the formative elements of the head similar to the division of the vertebral or mesoblastic somites of the trunk ; and yet there are not wanting proofs that the development of the head takes place in its earlier phases on essentially the same plan, and from the same blastodermic elements as the axial part of the trunk ; while there are also sufficient grounds for recognising in the later stages of the formation of the cartilaginous matrices, and in the ossification of the bones, indications of some degree of segmentation of the cranial and facial elements.

These indications are to be found mainly in 1, the prolongation of the notochord and its parachordal investment from the vertebral axis of the trunk into the cranial base ; 2, the enlargements of the notochord at certain places corresponding with the later separation of the bones ; 3, the division of the visceral arches and the extension of the body cavity into their substance, together with the formation of muscle-plates in each of them ; 4, the general similarity in the relations of the cranial and facial bases and the neural arches to the nervous centre and the issue of the nerves on the one hand, and of all these to the visceral or alimentary cavity on the other. But while these considerations would seem to indicate a morphological correspondence between cephalic and vertebral rudiments, much is still wanting to fill up the details of the comparison between them ; and, admitting the serial homology to exist, the number of metameric somites or divisions of the head is not as yet by any means determined.

II. DEVELOPMENT OF THE NERVOUS SYSTEM.

It is one of the most important generalisations resulting from modern embryological inquiry, as has been well remarked by Balfour, that all the organs of the nervous system take their origin from the epiblast, or from the same source as the cuticular covering of the body. And this fact is not confined to vertebrate animals, but is universal throughout the whole of the Metazoa.

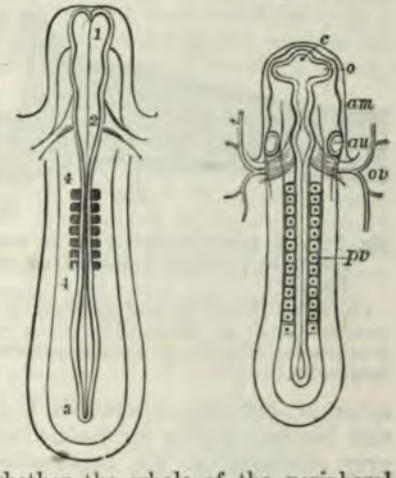
I. THE CEREBRO-SPINAL CENTRE.

In Vertebrates the first of these organs to appear is the great nervous centre comprising the brain and spinal cord in their primary rudimentary form of a simple medullary tube (as previously stated at p. 749) ; and

ıow ascertained that while the central organs are produced by an ıtion and rapid growth of the epiblast in the line of the vertebral f the body, the roots and part at least of the peripheral nerves are ›ped by secondary extension from the primary medullary centre.

Fig. 718.

Fig. 719.



8. Outline from above of the ıyo chick in the first half of second day.

2, the three primary encephalic enclosed in front and at the sides cephalic fold; 3, the hinder ex- of the medullary canal dilated rhomboid space in which is the ve trace; 4, 4, seven proto-vertebral

9.—Embryo of the dog more ıced, seen from above. (After off.)

medullary canal is now closed in; nterior encephalic vesicle; *o*, the ve optic vesicle; *au*, the primitive y vesicle opposite the third en- vesicle; *am*, the cephalic fold amnion; *ov*, the vitelline veins g the heart posteriorly; *pv*, the rtebral somites.

is not yet fully ascertained whether the whole of the peripheral s are derived from this source or are formed by secondary differen- n from blastema in the more remote seats of their origin.

›m what has been previously stated it will have been seen that the ıent of the cerebro-spinal nervous centre is formed more immedi- from the thickened medullary plates of the involuted epiblast, the s of which, rising from the surface of the blastoderm, become united lly along the middle line so as to close in a hollow medullary tube of ndrical form. This tube is wider at its anterior or cephalic extre- and this dilated portion becomes divided by partial constrictions, into two, and very soon after into three *primary cerebral or halic vesicles*, which represent anterior, middle and posterior

Fig. 720.

20.—Transverse sec- through the embryo he chick and blasto- at the end of first day. Magnified 90 to 100 times. n Kölliker.)

piblast; *dd*, hypoblast; *sp*, mesoblast; *Pv*, medullary groove; *m*, medullary *ch*, chorda dorsalis; *ucp*, proto-vertebral plate; *uch*, commencement of division oblast into its upper and lower laminæ; between *Rf* and *h* the dorsal laminæ or which by their approximation close in the medullary canal.

ry divisions of the brain. The spinal portion retains a more rm cylindrical shape, excepting towards the caudal extremity, it is longer in being formed, and remains for a time a flat open boidal dilatation. The continuous cavity enclosed within the tive medullary tube is the same with that which, variously modi-

fied, afterwards constitutes the central ventricles of the brain and canal of the spinal cord.

The formative cells composing the medullary substance are at first

Fig. 721.

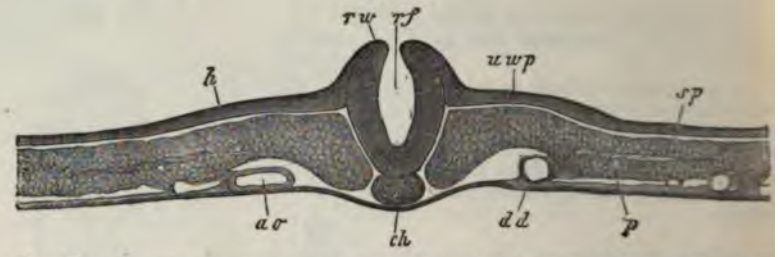


Fig. 721.—TRANSVERSE SECTION OF AN EMBRYO CHICK OF THE LATTER HALF OF THE SECOND DAY, AT THE PLACE WHERE THE VERTEBRAL SOMITES CEASE. $\frac{90}{1}$. (From Kölliker.)

rw, dorsal ridges; *rf*, medullary groove, or canal beginning to close; *uwp*, proto-vertebral plate; *sp*, lateral plate of the mesoblast; *h*, epiblast; *dd*, hypoblast; *ao*, primitive double aorta; *sp*, commencement of division of the mesoblast which forms the body-cavity.

spherical, but they afterwards become elongated and spindle-shaped and increase rapidly by multiplication. They represent at first the grey substance, or the nerve-cells and non-medullated fibres. The

Fig. 722.

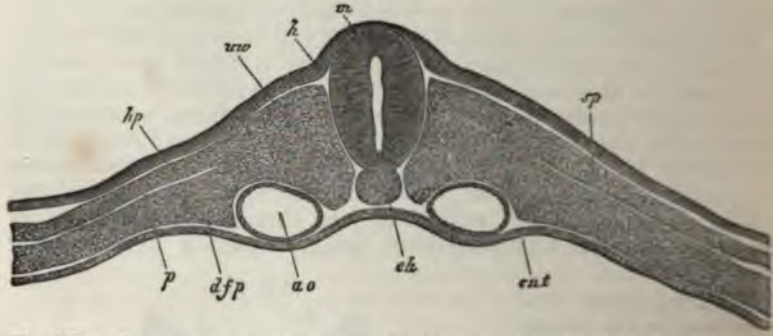


Fig. 722.—TRANSVERSE SECTION OF THE EMBRYO CHICK IN THE LATTER HALF OF THE SECOND DAY, IN THE REGION OF THE PROTO-VERTEBRÆ. $\frac{150}{1}$. (From Kölliker.)

m, medullary tube; *h*, epiblast now separated from the medullary inflection; *uw*, proto-vertebral mass; *hp*, parietal or somatic mesoblast; *dfp*, visceral mesoblast; *p*, pleuro-peritoneal or body-cavity between these two layers; *ch*, notochord; *ao*, aorta still double; *ent*, hypoblast.

cylindrical cells which, from the first, line the whole canal, remain permanently in some parts of it, and frequently present the ciliated structure.

THE SPINAL CORD.

The internal grey substance of the spinal cord is first formed; the white substance is produced later on the exterior. The sides acquire considerable increased thickness, while the dorsal and ventral parts

remain comparatively thin, so that the cavity assumes in section the appearance of a slit, which becomes gradually narrower as the lateral thickening increases; and at last the opposite surfaces uniting in the middle divide the primary central canal into an anterior or lower and posterior or upper part (see figs. 724 and 725).

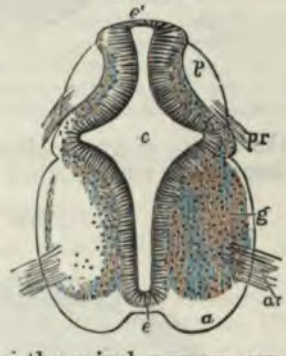
The lower of these divisions becomes the permanent central canal, the upper or dorsal is afterwards so far obliterated that it is filled with a septum of connective tissue belonging to the pia mater, and becomes the posterior fissure of the cord (in human anatomy) (Lockhart Clarke, No. 188).

In birds and mammals there is no distinction to be seen at first between the outer or corneous layer of the involuted epiblast and the cells which by their increase more immediately constitute the medullary plates. In batrachia, however, the dark colour of the corneous layer shows it to be distinct from a deeper layer which is the more strictly nervous. In Osseous fishes, and some other animals, there is no open medullary groove or canal at first, but an involution of a solid column of epiblast, which subsequently becomes hollow for the formation of a ventricular cavity.

Fig. 723.—Transverse section of the cervical part of the spinal cord of a human embryo of six weeks. (From Kolliker.) $\frac{20}{1}$

This and the following figure are only sketched, the white matter and a part of the grey not being shaded in. *c*, central canal; *e*, its epithelial lining, at *e* (inferiorly), the part which becomes the anterior commissure; at *é* (superiorly), the original place of closure of the canal; *a*, the white substance of the anterior columns, beginning to be separated from the grey matter of the interior, and extending round into the lateral column, where it is crossed by the line from *g*, which points to the grey substance; *p*, posterior column; *ar*, anterior roots; *pr*, posterior roots.

Fig. 723.



The masses of grey matter first formed in the spinal marrow correspond chiefly with the anterior columns. These are succeeded by lateral masses or columns, and somewhat later by small posterior columns. There are at first no commissures except by the passage of the deepest layer of cells across the middle line, but the fibres from the roots of the nerves when formed are traceable into the grey substance of their respective anterior and posterior columns.

The white substance is formed external to or on the surface of the deeper grey substance; but it is not yet determined whether it is wholly developed out of the cells composing the grey matter or from separate blastema to which the mesoblast may in part contribute. It is certainly combined with connective tissue elements, and its mode of formation is different from that of the grey substance, which is the more direct product of differentiation of the involuted epiblastic cells. How far the mesoblast takes part in the formation of the latter is still doubtful (see p. 192).

On the fifth and sixth days in the chick, according to Foster and Balfour, the white columns increase rapidly in size, and the anterior median fissure begins to be formed between the anterior columns by their swelling outwards and leaving its interval between them. It is at

first wide and shallow, and soon receives a lining of vascular connective tissue or pia mater. The commissures are now also formed; the anterior grey commissure first, then the posterior grey, and somewhat later the anterior white commissure.

Fig. 724.

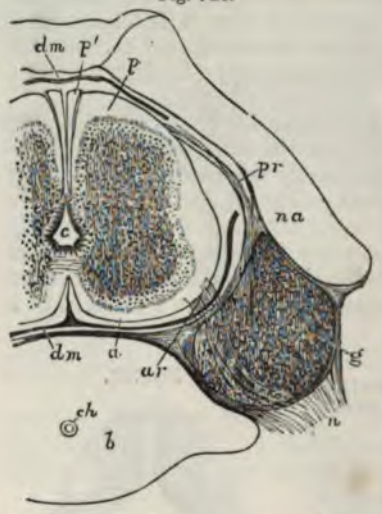


Fig. 724.—TRANSVERSE SECTION OF HALF THE CARTILAGINOUS VERTEBRAL COLUMN AND THE SPINAL CORD IN THE CERVICAL PART OF A HUMAN EMBRYO OF FROM NINE TO TEN WEEKS. (From Kölliker.) P

c, central canal lined with epithelium; *a*, anterior column; *p*, posterior column; *p'*, band of Goll; *g*, ganglion of the posterior root; *p r*, posterior root; *a r*, anterior root passing over the ganglion; *d m*, dura-matral sheath, omitted near *p r*, to show the posterior roots; *b*, body of the vertebra; *c h*, chorda dorsalis; *n a*, neural arch of the vertebra.

In the further increase of the anterior and lateral white columns as they thicken, they become more united together on each side, so that they can only be arbitrarily distinguished; the fibres of the roots of the nerves are traced through them into the grey matter; the cornua of grey matter become more and more developed, and the fissures between the white columns deepen, while the connective tissue

Fig. 725.

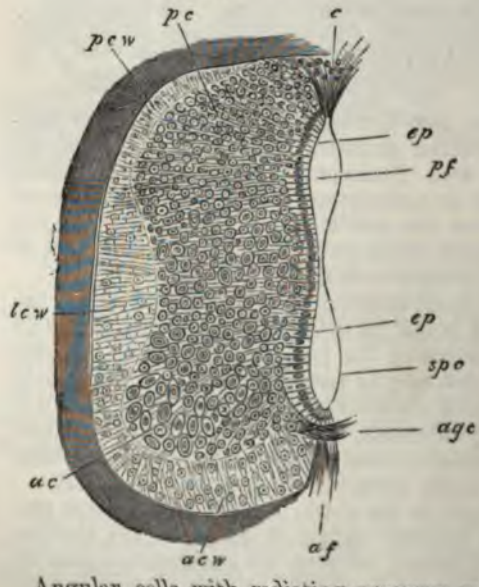


Fig. 725.—TRANSVERSE SECTION OF HALF OF THE SPINAL CORD OF THE CHICK OF SEVEN DAYS. (From Foster and Balfour.) MAGNIFIED.

pcw, posterior, *lcw*, lateral, and *acw*, anterior white columns; *pc*, posterior cornua of grey matter with small cells; *ac*, anterior grey cornua with large cells; *ep*, epithelium of the canal; *c*, the upper part now open and filled with tissue in the posterior fissure; *spc*, the lower division of the primitive medullary cavity, which remains as the permanent canal; *af*, anterior fissure left between the projecting anterior columns; *agc*, anterior grey commissure; *pf*, posterior fissure.

or pia-matral septa run more completely inwards through the white substance.

Angular cells with radiating processes make their appearance in the

grey matter, and the nerve-fibres both of the grey and white matter become more distinct.

The cylindrical cells lining the central canal retain their distinctness, and they are more completely separated from the grey matter by the delicate tissue of the ependyma. Throughout the greater part of the spinal cord the dorsal part of the primary medullary hollow is obliterated to form the fissure, but in the sacral region of birds it opens out in the rhomboidal sinus, and in the filum terminale of the human cord the whole primary medullary cavity remains.

The SPINAL CORD has been found by Kölliker already in the form of a cylinder in the cervical region of a human embryo of four weeks. Ununited borders have been seen by Tiedemann in the ninth week towards the lower end of the cord, the perfect closing of the furrow being delayed in that part, which is slightly enlarged, and presents a longitudinal median slit, analogous to the rhomboidal sinus in birds.

The *anterior fissure* of the cord is developed very early, and contains even from the first a process of the pia mater developed from mesoblast.

The *cervical* and *lumbar enlargements*, opposite the attachments of the brachial and crural nerves, appear at the end of the third month : in these situations the central canal, at that time not filled up, is somewhat larger than elsewhere (see figs. 733 and 736).

At first the cord occupies the whole length of the vertebral canal, so that there is no cauda equina. In the fourth month the vertebræ begin to grow more rapidly than the cord, so that the latter seems as it were to have been retracted within the canal, and the elongation of the roots of the nerves which gives rise to the *cauda equina* is commenced. At the ninth month, the lower end of the cord is opposite the third lumbar vertebra. (Kölliker, Lockhart Clarke, Bidder und Kupffer, Foster and Balfour.)

The origin of the roots of the spinal nerves will be referred to later.

THE BRAIN OR ENCEPHALON.

1. *General phenomena of development as ascertained in birds and mammals.*—Reference has previously been made to the simple form in which the brain at first presents itself in the anterior dilated portion of the primitive medullary tube, and its partial division into the three primary cerebral vesicles. These primary vesicles are named fore-brain, mid-brain, and hind-brain, and correspond most nearly to the regions of the third ventricle, the corpora quadrigemina and the medulla oblongata of the adult brain.

The changes which mainly tend to modify the form of this primitive brain are, 1st, the development on each side from the anterior vesicle of the primitive ocular vesicle; 2nd, the protrusion somewhat later from the forepart of the anterior cerebral vesicle of a bulging part, at first single or undivided, but which by a median cleft and lateral expansion becomes later the rudiment of the two cerebral hemispheres; and 3rd, the formation in the forepart of the posterior vesicle of a new encephalic rudiment corresponding to the cerebellum. Thus the first vesicle becomes converted into the cerebral hemispheres and vesicle of the third ventricle or thalamencephalon, the middle vesicle remains undivided, and the hinder vesicle becomes the cerebellum and medulla oblongata.

The formation of the primitive ocular vesicles, by an evolution of the lateral wall of the primitive medullary tube, gives to the first vesicle and the adjacent part of the head a much greater lateral width; but the cranial wall, though pushed out by the enlarging ocular vesicles, does

not follow closely the inflection of their surfaces. As the subsequent contraction of the stalk of the ocular vesicles progresses, these

Fig. 726.

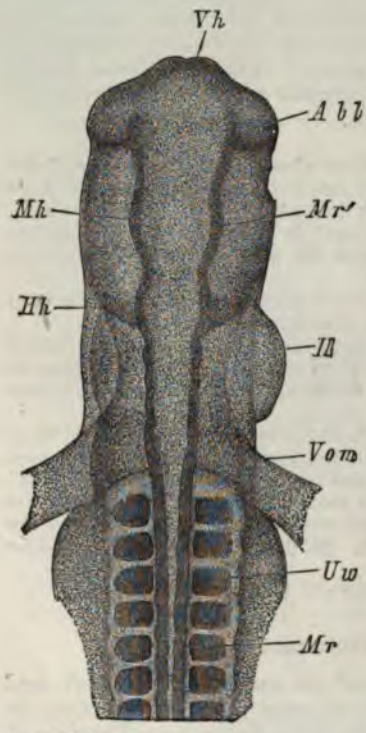


Fig. 726.—Fore-part of the embryo shown in fig. 689, viewed from the dorsal side. ♀. (From Kölliker.)

Vh, fore-brain ; *Abl*, ocular vesicles ; *Mh*, mid-brain ; *Hb*, hind-brain ; *H*, part of the heart seen bulging to the right side ; *Vom*, omphalo-mesenteric or vitelline veins entering the heart posteriorly ; *Mr*, medullary canal, spinal part ; *Mr'*, medullary wall of the mid-brain ; *Uw*, proto-vertebral somites.

vesicles are thrown more backwards and downwards by the development of the cerebral vesicles.

As the cerebral vesicles become enlarged, the cranial wall undergoes a corresponding expansion in the forepart of the head, the cavities of the lateral ventricles extend into their interior, and the vesicle of the thalamencephalon, which was at first the foremost part of the embryo-head, is thrown backwards into a somewhat deeper position.

The middle encephalic vesicle, increasing greatly in size, takes the most prominent part of the head superiorly, both from its own greater relative magnitude, and from the sudden bend which the head now takes below this vesicle in the great cranial flexure.

The formation of the cerebellum begins by a thickening in the upper

Fig. 727.

Fig. 727.—Four views of the brain of an embryo kitten in the stage of first division into the five cerebral rudiments, magnified three diameters. (From Reichert.)

A, from above ; B, from the side ; C, vertical section showing the interior ; D, from below.

1, Cerebral hemisphere, prosencephalon ; 2, thalamencephalon ; 3, mesencephalon, still single ; 4, cerebellum, epencephalon ; 5, myelencephalon, medulla oblongata ; o, optic nerves ; V, fifth pair ; VIII, eighth pair or glossopharyngeal and pneumogastric ; i, infundibulum ; v, v', general ventricular cavity, opening at v into the lateral ventricle by the foramen of Monro.

and lateral walls of the part of the posterior primitive vesicle which is next to the mid-brain, and is accompanied by a deep inflection of the medullary tube between it and the remaining part of the vesicle which forms the medulla oblongata.

At the same time that these changes are progressing, two other remarkable phenomena occur, which, as presenting themselves very constantly in the brains of vertebrates, and having important morphological relations, may be mentioned at this place. These phenomena are both related to the thalamencephalon, and they consist, 1st, in the downward projection of a pointed funnel-shaped part of the cerebral wall, with a prolongation of the ventricular cavity within it, into the pituitary fossa,

Fig. 728.—Longitudinal section through the brain of Scyllium canicula at an advanced stage of development. (From Balfour.)

cer, cerebral hemisphere; *pn*, pineal gland; *op.th*, optic thalamus; *op*, optic chiasma; *pt*, pituitary body; *in*, infundibulum; *cb*, cerebellum; *au.v*, recessus vestibuli, or passage from the auditory vesicle to the exterior; *met*, medulla oblongata; *c.in*, internal carotid artery.

Fig. 728.

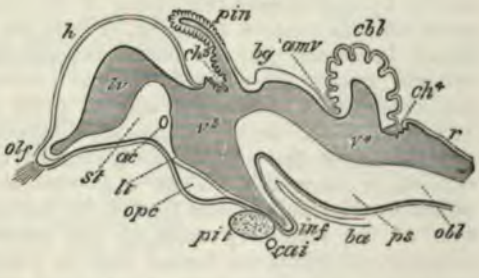
preparatory to its union with the evoluted part of the mouth cavity by which the pituitary gland takes its rise; and 2nd, in the thinning of the dorsal wall of the brain, and the prolongation of a part of that wall, which in the lower vertebrates reaches the cranial roof by a peculiar tubular extension, and is the homologue of the pineal gland.

There are thus distinguished the rudiments of five fundamental constituents of the brain, under which it will be found convenient to bring

Fig. 729.—Outline of a longitudinal section through the brain of a chick of ten days. (After Mihalkovics.)

h, cerebral hemisphere; *olf*, olfactory lobe and nerve; *st*, corpus striatum; *lv*, lateral ventricle; *ac*, anterior commissure; *lt*, lamina terminalis; *opc*, optic commissure; *pit*, pituitary gland; *inf*, infundibulum; *cai*, internal carotid artery; v^3, third ventricle; ch^3, choroid plexus of third ventricle; *pin*, pineal gland; *bg*, corpora bigemina; *amv*, anterior medullary velum; below which two last references are the aqueduct of Sylvius and crura cerebri; *cbl*, cerebellum; v^4, fourth ventricle; *ba*, basilar artery; *ps*, pons Varolii; ch^4, choroid plexus of the fourth ventricle; *obl*, medulla oblongata; *r*, roof of fourth ventricle.

Fig. 729.



the notice of the development of the several parts forming the full-grown organ, and which may in this association be shortly enumerated as follows, viz.:—

1. The cerebral hemispheres, with their ventricular hollows or lateral

ventricles, the corpora striata, and the olfactory lobes,—a set of parts to which, as a whole, the name of *procerebrum* or *prosencephalon* may be given.

2. The *thalamencephalon* with its cavity or third ventricle, the primary ocular pedicles, and the infundibulum.

3. The *mesencephalon*, which is the same with the original middle vesicle, and comprises the corpora quadrigemina and crura cerebri with its contracted internal hollow, the iter a tertio ad quartum ventriculum of human anatomy.

4. The next part in succession is the *cerebellum*, along with which is included the pons Varolii and part of the fourth ventricle.

5. The hinder part, which passes into the spinal marrow, is the medulla oblongata, with the remainder of the fourth ventricle and its continuation into the central spinal canal.

Fig. 730.

Fig. 730.—SKETCHES OF THE PRIMITIVE PARTS OF THE HUMAN BRAIN. (From Kölliker.)

1, 2, and 3 are from the human embryo of about seven weeks. 1, view of the whole embryo from behind, the brain and spinal cord exposed; 2, the posterior, and 3, the lateral view of the brain removed from the body; *h*, the cerebral hemisphere (prosencephalon); *i*, the thalamencephalon; *i'*, the infundibulum at the lower part of the same; *m*, the middle primary vesicle (mesencephalon); *c*, the cerebellum (epencephalon); *mo*, the medulla oblongata. Figure 3 shows also the several curves which take place in the development of the parts from the primitive medullary tube. In 4, a lateral view is given of the brain of a human embryo of three months: the enlargement of the cerebral hemisphere has covered in the optic thalami, leaving the tubercula quadrigemina, *m*, apparent.

In these five fundamental parts or rudiments of the brain, arising out of very simple modifications of the three primary encephalic vesicles, it is mainly by an increased thickening of the medullary wall in some of the parts, and the relative thinning, or even the entire removal of the substance in others, that the changes accompanying the formation of the cerebral masses are effected, while as a consequence of these and other modifications of form, the several parts of the internal cavity, or ventricles of the brain, acquire the different degrees of expansion and contraction, or the comparatively open or closed condition which they exhibit in after life. Thus the cerebral hemispheres and corpora striata are the main masses formed by the lateral thickening and expansion of the medullary walls of the procerebrum, while the corpus callosum and fornix are formed later by a deeper median development in connection with these parts: the thalami optici are the most solid parts of the lower and lateral region of the second rudiment: the corpora quadrigemina are thickenings of the upper wall of the third rudiment, while the crura cerebri arise by increased deposit in its lower part; the cerebellum may be regarded as a large deposit in the upper wall of the fourth rudiment, while the pons Varolii is a thickening of its lower wall; and the parts composing the medulla oblongata are principally formed by increased deposit in the lower and lateral wall of the fifth rudiment.

Thus, also, the lateral ventricles are two expansions of the forepart of the original ventricular cavity which result from the dilatation of the vesicles of the right and left cerebral hemispheres, and communicate with the central or third ventricle by the common foramen of Monro. The central or third ventricle, originally the foremost part of the medullary hollow, is narrowed on the sides by the increased development

Fig. 731.

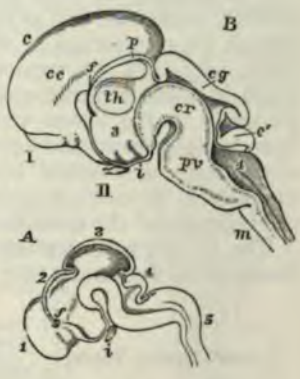


Fig. 731.—VERTICAL SECTIONS OF EMBRYONIC BRAINS IN TWO STAGES OF TRANSITION FROM THE RUDIMENTARY CONDITION, MAGNIFIED THREE DIAMETERS. (From Reichert.)

A, Brain of the embryo pig in commencing state of transition. 1, Right cerebral hemisphere; 2, thalamencephalon and position of the pineal gland; 3, mid-brain, with a large cavity; *f*, foramen of Monro; *i*, infundibulum; 4, cerebellum; 5, medulla oblongata.

B, Brain of the embryo of the cat, more advanced. *c*, Cerebral hemisphere passing backwards so as to cover the other parts; I, olfactory bulb; II, optic nerve; *th*, thalamus opticus; *f*, foramen of Monro; *cc*, corpus callosum; *p*, pineal gland; *i*, infundibulum; *cq*, corpora quadrigemina, not yet divided; 3, third ventricle; *cr*, crura cerebri, below the aqueduct of Sylvius, now reduced in width; *c'*, cerebellum; 4, fourth ventricle; *pv*, Pons Varolii; *m*, medulla oblongata.

of the thalami optici, while inferiorly it is prolonged and projects downwards as infundibulum into the pituitary fossa; and on the upper side the wall of this ventricle comes to be opened up by the thinning away of its medullary substance, and otherwise modified in connection with the formation of the pineal gland. The continuation backwards of the original ventricular hollow, greatly narrowed by the ultimate thickening of the substance of the corpora quadrigemina and crura cerebri, forms the aqueduct of Sylvius, and is succeeded by the more expanded cavity

Fig. 732.

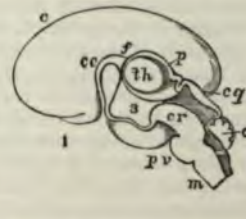


Fig. 732.—VERTICAL SECTION OF THE BRAIN OF A HUMAN EMBRYO OF FOURTEEN WEEKS, MAGNIFIED THREE DIAMETERS. (From Reichert.)

c, cerebral hemisphere; *cc*, corpus callosum beginning to pass back, *f*, foramen of Monro; *p*, membrane over the third ventricle and the pineal gland; *th*, thalamus opticus; 3, third ventricle; I, olfactory bulb; *cq*, corpora quadrigemina, mesencephalon; *cr*, crura cerebri, and above them the aqueduct of Sylvius still wide; *c'*, cerebellum, and below it the fourth ventricle; *pv*, Pons Varolii; *m*, medulla oblongata.

of the fourth ventricle, lying between the cerebellum and the lower wall. The upper wall of the latter cavity undergoes great thinning like that of the third ventricle, so as to be reduced in the part before the cerebellum to the thin lamina forming the valve of Vieussens, and in the part behind it to be covered only by membrane, and to present an opening from the cavity into the posterior sub-arachnoid space.

From what has before been said of the relation of the fundaments[1] parts of the brain to the basis of the skull, it will be seen that the cer

bral development is intimately connected also with the great cranial flexure which occurs at the pituitary fossa; for while the infundibular prolongation of the thalamencephalon projects down into this fossa, and the lamina terminalis lies in front in the position of the original foremost part of the encephalon, certain parts of the brain may be considered as situated posterior to this point, viz., the mesencephalon with crura cerebri, cerebellum with pons Varolii, and medulla oblongata, while the cerebral hemispheres, with the corpora striata, corpus callosum, and fornix, may be considered as formed in their earlier condition by forward expansion, and as situated in front of this turning point. But though the connections of the cerebral hemispheres with the rest of the brain may thus be regarded as anterior to the cranial centre, and while in their earlier stages, and still of small size, they are actually placed as in the lowest vertebrates entirely in front of it, yet by the later great proportional development in the higher animals, and especially in man, the cerebral hemispheres come to progress backwards, and successively to cover superiorly the thalami, corpora quadrigemina, the cerebellum, and the medulla oblongata.

The developmental relation of the several parts of the brain to its fundamental rudiments may be stated in the following tabular form:

I. Anterior primary Vesicle,	1. Prosencephalon.* Fore-brain.	Cerebral Hemispheres, Corpora Striata, Corpus Callosum, Fornix, Lateral Ventricles, Olfactory bulb (Rhinencephalon).
	2. Thalamencephalon. (Diencephalon.) Inter-brain.	Thalami Optici, Pineal gland, Pituitary body, Third Ventricle, Optic nerve (primarily).
II. Middle primary Vesicle,	3. Mesencephalon. Mid-brain.	Corpora Quadrigemina, Crura Cerebri, Aqueduct of Sylvius, Optic nerve (secondarily).
III. Posterior primary Vesicle.	4. Epencephalon. Hind-brain.	Cerebellum, Pons Varolii, anterior part of the Fourth Ventricle.
	5. Metencephalon. After-brain.	Medulla Oblongata, Fourth Ventricle, Auditory nerve.

(See the reference to works on the development of the brain under the Nos. 184—194.)

FARTHER DEVELOPMENT OF THE BRAIN IN MAN AND MAMMALS.

The full history of the development of the brain is so extensive and complicated a subject that it will be necessary to limit ourselves here to a very brief indication of the principal facts regarding it, proceeding from behind forwards in the order of the five fundamental parts of the brain above-mentioned.

1. Medulla Oblongata, Metencephalon, After-brain.—The medullary roof of this part becomes at an early period more and more widened out laterally, and reduced in thickness till at last scarcely any nervous substance remains, and the lateral parts, along with the inferior, thickening by the great increase of the medullary tissue, are thrown towards the side, and thus give rise to the wide space which forms the fourth ventricle, bounded posteriorly by the narrowing calamus scriptorius, and leading at its point into the canal of the spinal marrow. There is subsequently formed in the roof the opening which leads from the fourth ventricle into the subarachnoid space, and the pia mater, rich in blood-vessels, becomes folded over the roof and forms the plexus known as the choroid of the fourth ventricle.

The three more solid constituent parts of the medulla oblongata begin to be

* This and the four following terms are adopted as applicable to the principal secondary divisions of the primary medullary tube, and as corresponding to the commonly received names of the German embryologists, viz., Vorderhirn, Zwischenhirn, Mittelhirn, Hinterhirn, and Nachhirn, or their less used English translations, given above.

distinguishable about the third month; first the *restiform* bodies, which are connected with the commencing cerebellum, and afterwards the anterior pyramids and olives. The *anterior pyramids* become prominent on the surface and distinctly defined in the fifth month; and by this time also their decussation is evident. The *olivary* fasciculi are early distinguishable, but the proper *olivary body*, or tubercle, does not appear till about the sixth month. The *fasciolæ cinereæ* of the fourth ventricle can be seen at the fourth or fifth month, but the *white striæ* not until after birth.

2. The Cerebellum. Epencephalon, Hind-brain.—In the human embryo the cerebellum exists at the end of the second month, as a thin medullary lamina, forming, as in many of the lower vertebrate animals, an arch behind the corpora quadrigemina across the wide primitive medullary tube.

According to Bischoff, the cerebellum does not commence, as was previously supposed, by two lateral plates which grow up and meet each other in the middle line; but a continuous deposit of nervous substance takes place across this part

Fig. 733.—Brain and spinal cord exposed from behind in a fœtus of three months. (From Kölliker.)

h, the hemispheres; *m*, the mesencephalic vesicle or corpora quadrigemina, *c*, the cerebellum; below this are the medulla oblongata, *mo*, and fourth ventricle, with remains of the membrana obturatoria. The spinal cord, *s*, extends to the lower end of the sacral canal, and presents the brachial and crural enlargements.

Fig. 733.

of the medullary tube, and closes it in at once. This layer of nervous matter, which is soon connected with the corpora restiformia, or inferior peduncles, increases gradually up to the fourth month. The middle lobe is the first formed, and remains for a considerable time the principal mass of the cerebellum. The lateral lobes follow, and there is seen about the fifth month a division of these into the subordinate lobes; at the sixth, these lobes send out *folia*, which are at first simple, but afterwards become subdivided. Moreover, the *hemispheres* of the cerebellum are now relatively larger than its median portion, or *worm*. In the seventh month the organ is more complete, and the *flocculus* and *posterior velum*, with the other parts of the inferior vermiform process, are now distinguishable, except the *amygdalæ*, which are later in appearing.

Of the *peduncles* of the cerebellum, the *inferior* pair (corpora restiformia) are the first seen—viz., about the third month; the *middle* peduncles are perceptible in the fourth month; and at the fifth, the *superior* peduncles and the Vieussenian valve. The *pons Varolii* is formed, as it were, by the fibres from the hemispheres of the cerebellum embracing the pyramidal and olivary fasciculi of the medulla oblongata below. According to V. Baer, the bend which takes place at this part of the encephalon thrusts down a mass of nervous substance before any fibres can be seen; and in this substance transverse fibres, continuous with those of the cerebellum, are afterwards developed. From its relation to the cerebellar hemispheres the pons keeps pace with them in its growth; and, in conformity with this relation, its transverse fibres are few, or entirely wanting in those animals in which there is a corresponding deficiency or absence of the lateral parts of the cerebellum, as in marsupials and monotremes.

3. The Mesencephalon, Mid-brain.—The *corpora quadrigemina* are formed in the upper part of the middle cephalic vesicle; the hollow in the interior of which communicates with those of the first and third vesicles. The corpora quadrigemina, in the early condition of the human embryo, are of great proportionate volume, in harmony with what is seen in the lower vertebrata; but subsequently they do not grow so fast as the anterior parts of the encephalon, and are therefore soon overlaid by the cerebral hemispheres, which at the sixth month

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Fig. 735.

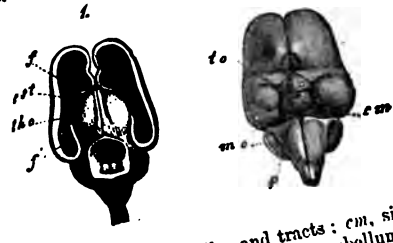

Fig. 735.—Brain of the human embryo of three months. Nat. size. (From Kölliker.)

In 1 the view is from above
upper part of the cerebral hemi
and mesencephalon having b
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cm, single mass of the corpora mammill
mo, medulla oblongata, are

this the olfactory bulbs and tracts; *cm*, single mass of the corpora mammillaria; *mo*, medulla oblongata; *p*, pons Varolii. The cerebellum and medulla oblongata are divided; *p*, pons Varolii. The cerebellum and medulla oblongata, *mo*, are and to the sides in both figures.

cavity. The medullary roof of this part on the other hand thins d
and is at last reduced only to a folded membrane, in connection with
of which the choroid plexus of the third ventricle is formed. The
of the roof is developed by a peculiar process to be noticed later i
gland, which remains united on each side by its pedicles to the
behind these a transverse band is formed as posterior commissure.
The lamina terminalis (lamina cinerea) continues to close the
below it the optic commissure forms the floor of the

cover them completely. Moreover, they become gradually solid by the deposition of matter within them; and as, in the meantime, the *cerebral peduncles* are increasing rapidly in size in the floor of this middle cephalic vesicle, the cavity in its interior is quickly filled up, with the exception of the narrow passage named the *Sylvian aqueduct*. The fillet is distinguishable in the fourth month. The corpora quadrigemina of the two sides are not marked off from each other by a vertical median groove until about the sixth month; and the transverse depression separating the anterior and posterior pairs is first seen about the seventh month of intra-uterine life.

Fig. 734.

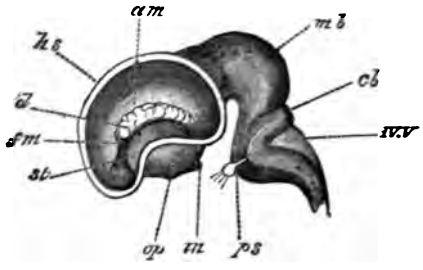


Fig. 734.—Lateral view of the brain of an embryo calf of 2½ cm. (From Balfour, after Mihalkovics.)

The outer wall of the left hemisphere is removed to show the interior of the lateral ventricle; *h*, cut wall of the hemisphere; *s*, corpus striatum; *ha*, hippocampus major; *d*, choroid plexus of ventricle; *fm*, foramen of Monro; *op*, optic tract; *in*, infundibulum; *mb*, mid-brain; *cb*, cerebellum; IV.V, roof of fourth ventricle; *pa*, pons Varolii with fifth nerve and Gasserian ganglion.

The internal geniculate bodies belong to this division of the brain.

4. The Thalamencephalon, Inter-brain.—It is from this part, constituting at first the whole and subsequently the hinder part of the anterior primary encephalic vesicle, that the optic vesicles are developed in the earliest period, and the forepart is that in connection with which the cerebral hemispheres and accompanying parts are formed. The thalamus opticus of each side is formed by a lateral thickening of the medullary wall, while the interval between, descending towards the base, constitutes the cavity of the third ventricle with its prolongation in the infundibulum. The grey commissure afterwards stretches across the ventricle

Fig. 735.

Fig. 735.—Brain of the human embryo of three months. Natural size. (From Kölliker.)

In 1 the view is from above, the upper part of the cerebral hemispheres and mesencephalon having been removed. *f*, fore part of the divided wall of the hemisphere; *f'*, hind part of the same which becomes the hippocampus turned in; *cst*, corpus striatum; *tho*, thalamus opticus.

In 2 the lower surface is represented. *to*, tractus opticus; and in front of this the olfactory bulbs and tracts; *cm*, single mass of the corpora mammillaria not yet divided; *p*, pons Varolii. The cerebellum and medulla oblongata, *mo*, are seen behind and to the sides in both figures.

cavity. The medullary roof of this part on the other hand thins down rapidly and is at last reduced only to a folded membrane, in connection with the pia mater of which the choroid plexus of the third ventricle is formed. The hinder part of the roof is developed by a peculiar process to be noticed later into the pineal gland, which remains united on each side by its pedicles to the thalamus, and behind these a transverse band is formed as posterior commissure.

The lamina terminalis (lamina cinerea) continues to close the third ventricle in front, below it the optic commissure forms the floor of the ventricle, and

further back the infundibulum descends to be united in the sella turcica with the tissue adjoining the posterior lobe of the pituitary body.

The two *optic thalami*, formed from the posterior and outer part of the anterior vesicle, consist at first of a single hollow sac of nervous matter, the cavity of which communicates on each side in front with that of the commencing

Fig. 736.—Brain and spinal cord of a fœtus of four months, seen from behind. (From Kölliker.)

h, hemispheres of the cerebrum; *m*, corpora quadrigemina or mesencephalon; *c*, cerebellum; *mo*, medulla oblongata, the fourth ventricle being overlapped by the cerebellum; *s s*, the spinal cord with its brachial and crural enlargements.

Fig. 736.

cerebral hemispheres, and behind with that of the middle cephalic vesicle (corpora quadrigemina). Soon, however, by increased deposit taking place in their interior behind, below, and at the sides, the thalami become solid, and at the same time a cleft or fissure appears between them above, and penetrates down to the internal cavity, which continues open at the back part opposite the entrance of the Sylvian aqueduct. This cleft or fissure is the *third ventricle*. Behind, the two thalami continue united by the *posterior commissure*, which is distinguishable about the end of the third month, and also by the *peduncles of the pineal gland*. The *soft commissure* probably exists from an early period, although it could not be detected by Tiedemann until the ninth month.

At an early period the *optic tracts* may be recognised as hollow prolongations from the outer part of the wall of the thalami while they are still vesicular. At the fourth month these tracts are distinctly formed. They subsequently are prolonged backwards into connection with the corpora quadrigemina.

The formation of the pineal gland and pituitary body presents some of the most interesting phenomena which are connected with the development of the thalamencephalon.

Pineal Gland. Epiphysis Cerebri.—As already stated, this body is formed by an out-folding from the back part of the inter-brain roof, at a place where the opposite sides remain united by nervous matter afterwards giving rise to the pineal peduncles. This body consists at first in all vertebrates of medullary substance covered by pia mater, and forms a median projection upwards, which in the lower tribes is also directed forwards in the form of a tube which reaches the roof of the cranium, and in some is united with or even passes through the cranial wall. It is in all deeply indented by vascular folds and growths of the pia mater. In mammals the original development of the pineal gland is the same as in the lower tribes; but it remains comparatively short, and its direction is backwards; and though it is at first permeated by epithelial tubes, or subdivisions of the ventricular cavity, it becomes at a later period solid by the deposit of various cellular and other materials. The gritty deposit was found in it by Sœmmerring at birth.

Pituitary body. Hypophysis Cerebri.—The general nature of this body in connection with an outgrowth of the brain on the one hand and a diverticulum of the alimentary canal on the other, and which was first pointed out by Rathke (1838, No. 195), has been already adverted to. The researches of W. Müller (No. 197), Goette (No. 200), and Mihalkovics (No. 198), have fully confirmed Rathke's view, and lead to the following general conclusions regarding it.

The infundibulum, as is well known, is a prolongation of the medullary wall of the third ventricle, originally in continuity with the epiblast; while the diverticulum from the alimentary canal is not, as was at one time supposed, from the pharynx, but from the mouth, and its lining is therefore continuous with the same layer of the blastoderm. This diverticulum is formed at an early period from

the middle of the upper and back part of the buccal cavity before the faucial opening into the pharynx has taken place. The anterior attenuated extremity of the notochord is placed between the cerebral and buccal outgrowths, but it disappears as the lower one extends upwards and comes to unite with the infundibulum, and then the notochord is lost in the floor of the pituitary fossa with which both the outgrowths cohere (Mihalkovics)

Fig. 737.

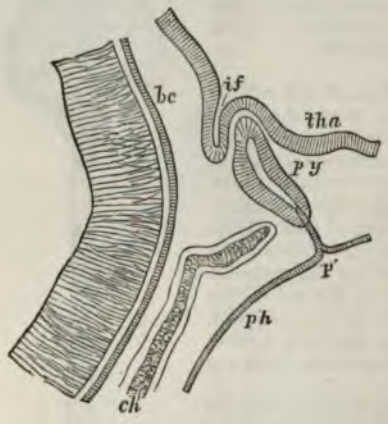


Fig. 737.—VERTICAL SECTION OF THE INFUNDIBULUM AND PITUITARY DIVERTICULUM IN THE RABBIT'S EMBRYO, AFTER THE OPENING OF THE FAUCES. (From Mihalkovics.)

For the earlier stages see fig. 705, p. 807, A and B. *bc*, dorsum sellæ; *if*, infundibulum; *tha*, floor of thalamencephalon; *py*, pituitary diverticulum, now closed; *p'*, stalk of original communication with the mouth; *ph*, pharynx; *ch*, notochord in the spheno-occipital part of the cranial basis.

The flask-like outgrowth of the buccal epiblast which gives rise to the hypophysis cerebri, is now gradually shut off from the corneous layer and cavity of the mouth by the constriction and subsequent closure of its communicating pedicle. There remains, however, for a considerable time, a longish thread of union between the two. The epithelium of the enclosed portion subsequently undergoes development into glandular cæca and cell-cords, and its internal cavity becomes gradually obliterated. This forms the anterior part or lobe of the pituitary body. The posterior part owes its origin in all vertebrates to the combination with mesoblastic tissue of a widened extension of the infundibular process of the brain, which is thrust in between the sac of the pituitary body and the dorsum sellæ. The nervous structure of this posterior lobe afterwards disappears in the higher animals, but in the lower the posterior lobe retains its place as a part of the brain.

The possibility of establishing a general homology between vertebrate and invertebrate animals, involves important considerations as to the relations of the forepart of the alimentary canal to the brain. In a recent memoir on this subject (No. 201), Professor Owen puts forward the view that the "conario-hypophysial tract," or passage through the pituitary diverticulum, infundibulum, third ventricle and pineal gland, may have been the means of carrying the anterior part of the alimentary canal from the ventral or hæmal to the dorsal or neural side of the head in an ancestral form of the vertebrate animal, and that thus (one of them being inverted) the several sets of organs in the two great divisions of the animal kingdom might be brought into corresponding relative position. According to the view taken by Dohrn (No. 199), the fourth ventricle is the place where the œsophagus may be supposed to have pierced the nervous ring.

5. Prosencephalon, Fore-brain.—Each *hemisphere-vesicle* may be considered to consist of two parts: one of these is the part which from the interior appears as the corpus striatum, and from the exterior as the island of Reil, or central lobe; the other forms the expanded or covering portion of the hemisphere, and is designated by Reichert the *mantle*. The lateral ventricles are placed internally between these parts. The aperture existing at the constricted neck of the ventricle where it expands into the hemispheres is the foramen of Monro.

The *corpora striata*, it will be observed, have a different origin from the optic thalami; for, while the latter are formed by thickening of the circumferential wall of a part of the first cerebral vesicle, and thus correspond in their origin with the parts of the encephalon behind them, the corpora striata appear as

thickenings of the floor of the hemisphere-vesicles, which are lateral off-shoots from the original medullary tube. On this account, Reichert considers the brain primarily divisible into the stem, which comprises the whole encephalon forwards to the tænia semicircularis, and the hemisphere-vesicles, which include the corpora striata and hemispheres.

The cerebral hemispheres undergo enlargement at an early period in mammals,

Fig. 738.

Fig. 738.—Semidiagrammatic views of the inner surface of the right cerebral hemisphere of the fœtal brain at various stages of development. (From Schmidt.)

1, 2, and 3, are from fœtuses of the respective ages of eight, ten, and sixteen weeks; 4, from a fœtus of six months. *a*, lamina terminalis or part of the first primary vesicle which adheres to the sella turcica; *b*, section of the cerebral peduncle as it passes into the thalamus and corpus striatum; the arched line which surrounds this bounds the great cerebral fissure; *c*, anterior part of the fornix and the septum lucidum; *d*, inner part of the arch of the cerebrum, afterwards the hippocampus major and posterior part of the fornix; *e*, corpus callosum very short in 3, elongated backwards in 4; in 4, *f*, the marginal convolution; *f'*, calloso-marginal fissure; *g*, gyrus fornicatus; *p'*, the parieto-occipital fissure descending to meet the calcarine fissure; I, olfactory bulb; F, P, O, T, frontal, parietal, occipital and temporal lobes.

and especially in the human embryo, so that at the tenth week they have greatly surpassed in size all the other parts of the brain. They then form large hollow bodies with comparatively thin walls superiorly, the lateral ventricles being greatly

Fig. 739.

Fig. 739.—View of the inner surface of the right half of the fœtal brain of about six months. (From Reichert.)

F, frontal lobe; P, parietal; O, occipital; T, temporal; I, olfactory bulb; II, right optic nerve; *fp*, calloso-marginal fissure; *p*, external; *p'*, internal parts of the parieto-occipital fissure; *h*, calcarine fissure; *g*, gyrus fornicatus; *c*, *c*, corpus callosum; *s*, septum lucidum; *f*, placed between the middle commissure and the foramen of Monro; *v*, in the upper part of the third ventricle immediately below the velum interpositum and fornix; *v'*, in the back part of the third ventricle below the pineal gland, and pointing by a line to the aqueduct of Sylvius; *v''*, in the lower part of the third ventricle above the infundibulum; *r*, recessus pinealis passing backwards from the tela choroidea; *pv*, pons Varolii; *Ce*, cerebellum.

dilated, and communicating by a wide aperture with each other, and with the third ventricle, by the foramen of Monro. The growth of the hemispheres takes place progressively from before backwards, so that they come to cover in succession the thalami, corpora quadrigemina and cerebellum, which all originally project in a series behind them, as they do permanently in the lowest vertebrates. By the end of the third month the hemispheres have extended so far backwards as to cover the thalami; at the fourth they reach the corpora quadrigemina; at the sixth they cover those bodies and great part of the cerebellum, beyond which they project still further backwards by the end of the seventh month.

The floor especially of the hemispheres thickens considerably, and the corpus striatum increasing greatly in magnitude, at the same time projects upwards into the lateral ventricles so as to give these cavities an arched form and mark out their anterior and descending cornua, while externally the distinction between the frontal and temporal lobes is indicated by the wide depression of the fissure of Sylvius. The floor of this part below the corpora striata becomes the island of Reil, or central lobe. The corpora striata and thalami, which are at first distinct, become more and more completely united together.

Fig. 740.

Fig. 740.—TRANSVERSE SECTION THROUGH THE BRAIN OF A SHEEP'S EMBRYO OF 2½ CM. IN LENGTH. (From Balfour, after Kölliker.)

The section passes through the hemispheres and third ventricle. *st*, corpus striatum; *th*, optic thalamus; *t*, third ventricle; *c'*, their divergence into the walls of the hemispheres; *l*, lateral ventricle with choroid plexus *pl*; *h*, hippocampus major; *f*, primitive falx; *a*, orbito-sphenoid; *sa*, presphenoid; *p*, pharynx; *ch*, chiasma; *o*, optic nerve; *mm*, foramen of Monro; *s*, covering of lateral ventricles.

A deep notch separates the hemispheres above and posteriorly, but in front they are united together in the place of the original lamina terminalis, and below as farther back the inner walls becoming thinner are united together in a narrow partition which is the source of the septum lucidum and the commissures. The first of these to arise is the anterior commissure, which is also the lowest and unites the corpora striata. The fornix comes next in its anterior part, which with its pillars and the corpora albicantia is at first single and median; the posterior pillars follow, running back on each side into the cornu Ammonis of the descending cornua. The corpus callosum is last formed, consisting at first only of its fore part, as is permanently the case in monotremes and marsupials; but as the hemispheres extend themselves backwards, the corpus callosum elongates

in the same direction, thus forming a roof for the subjacent lateral ventricles and other parts.

The fifth ventricle in the septum lucidum is not a part of the original common ventricular cavity of the brain, but is formed separately.

At the lower part of the inner walls two horizontal folds make their appearance below those of the fornix and hippocampi, which are covered by pia mater, and which, extending backwards from the foramen of Monro, cover in the third ventricle and occupy the great transverse fissure of the brain. These folds, extending themselves laterally and backwards, and becoming more and more plicated and vascular at the edges, give rise to the choroid plexus of the lateral ventricles and the velum interpositum.

The *olfactory lobes* are outgrowths from the lower and lateral parts of the cerebral hemispheres, being more immediately connected with the frontal lobes, but extending through the fissure of Sylvius as far as the temporal or middle lobes. They are at first hollow, and in some animals their cavity is in permanent communication with the lateral ventricles. In man they become solid at an early period.

Development of the Convolutions and Sulci.—Adopting the distinction of the convolutions and sulci of the cerebral hemispheres as of two kinds, viz., "primitive" and "secondary," according as the former result from a folding of

Fig. 741.

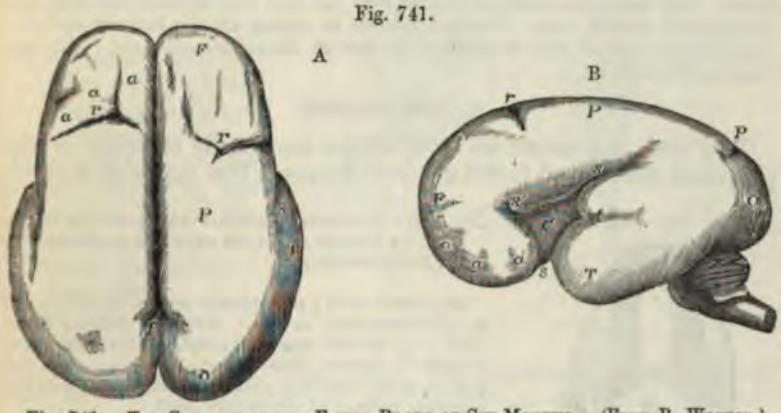


Fig. 741.—The Surface of the Fœtal Brain at Six Months. (From R. Wagner.)

This figure is intended to show the commencement of the formation of the principal fissures and convolutions. A, from above; B, from the left side. F, frontal lobe; P, parietal; O, occipital; T, temporal; *a*, *a*, *a*, slight appearance of the several frontal convolutions; *s*, the Sylvian fissure; *s'*, its anterior division; within it, C, the central lobe or convolutions of the island; *r*, fissure of Rolando; *p*, the parieto-occipital fissure.

the whole substance of the wall of the hemisphere, while the latter consist merely of depressions and elevations of its more superficial portion, it may be stated, with respect to their development, that the first of the primitive sulci to appear is the fissure of Sylvius, which is visible before the end of the third month (Ecker) as a wide shallow depression or fossa between the anterior and middle lobe of each hemisphere. Of the remaining primitive sulci, the hippocampal or dentate, the parieto-occipital and the calcarine, also begin to appear during the third month, and by the end of the fifth month are well established.

The secondary sulci begin to appear about the fifth or sixth month; the first of these to be seen is the sulcus centralis, or fissure of Rolando. By the end of the sixth month the transverse frontal and inferior frontal furrows have appeared on the otherwise smooth surface of the frontal lobe, and at about the same time the first indications of the intraparietal fissure, with its continuation on the occipital lobe as the superior occipital furrow, the parallel, the calloso-marginal

and collateral fissures become visible on the outer and inner aspects of the hemispheres. The lower surface now shows a slight trace of the inferior temporal furrow; and the fissure of Sylvius, which was at first a wide fossa, at this period begins to close in, especially at its hinder portion, an indication of its anterior division becoming now visible.

By the end of the seventh month nearly all the chief features of the cerebral convolutions and sulci have appeared. The superior frontal fissure can now be seen, and the three frontal convolutions are well marked. The fissure of Rolando has increased in length and depth. While the sulci that have already been spoken of are becoming better marked, the transverse occipital appears for the first time. Within the fissure of Sylvius, which has now a triangular form, two depressions are seen, the anterior bounding a prolongation of the olfactory tract, the posterior dividing the greater portion of the floor of the fissure into a fore and hind part. The island of Reil shows three convolutions divided by the forked sulcus insulæ primus. The sulci visible on the under surface of the hemispheres are still few and indistinct. Indications are found of a branched orbital sulcus, and of the olfactory sulcus, in which lie the olfactory bulb and tract. The middle temporal convolution, and the uncus and gyrus hippocampi, have now become fairly prominent.

During the eighth month a furrow appears behind the fissure of Rolando, parallel to it, and joining the intraparietal. This is the sulcus postcentralis of Ecker. The transverse occipital furrow now becomes very distinct, and joins the intraparietal farther back. The last fissures to appear are the inferior occipito-temporal and a small furrow crossing the end of the calloso-marginal. (Consult Nos. 28, 190, and 191.).

II. THE NERVES.

Very little was known till lately of the exact mode of origin of the peripheral nerves, and it was generally supposed that they were formed,

Fig. 742.

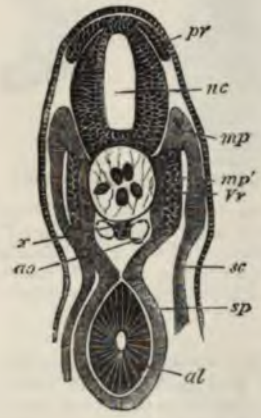


Fig. 742.—Transverse section through the trunk of an embryo shark, to show the neural crest. (From Balfour.)

nc, neural canal; *pr*, posterior root of spinal nerve; *x*, sub-notochordal rod; *ao*, aorta; *sc*, parietal mesoblast; *sp*, visceral mesoblast; *mp'*, muscle plate; *mp*, portion of muscle plate converted into muscle; *Vr*, portion of the vertebral plate which will give rise to the vertebral bodies; *al*, alimentary canal.

as held by Remak, in more or less immediate connection with the parts of mesoblastic origin in which they were distributed. The only known fact inconsistent with this view was that the anterior or motor roots of the spinal nerves had been found to bud out from the ventral side of the spinal cord. The recent researches especially of His, Balfour, and Marshall, Kölliker, Hensen and others, have thrown quite a new light on this subject, and have shown that all the peripheral nerves, cerebro-spinal and sympathetic, with their ganglia, emanate originally from the primary brain and spinal marrow, that they have therefore an epiblastic origin, and that they spread more or less from thence into the different parts of the body. (See Nos. 28 and 202—205.)

Spinal Nerves.—Following the description of their origin given by Balfour and Marshall, it may be stated that the posterior roots of the spinal nerves and most of the cranial nerves, with their respective ganglia, which

are formed before the anterior roots, proceed from a series of cellular swellings, constituting the *neural crest*, which are in continuity with the medullary plates close to the place of inflection of the epiblast into the involution which forms the primary brain and spinal cord. These root swellings are in some animals connected together by a longitudinal band or commissure. In the primitive projections there are soon distinguished a narrower first part or root, then a thicker part, the ganglion, and further down a part of the nerve extending beyond it. The root originally connected with the upper part of the medullary wall close to the median line slips down, as it were, upon the side, and is subsequently united laterally with the medullary wall at a lower place, leaving the upper end of the root for a time apparently free. This process begins in the chick at the end of the second day, and in the embryo of the rabbit on the ninth day.

Fig. 743.

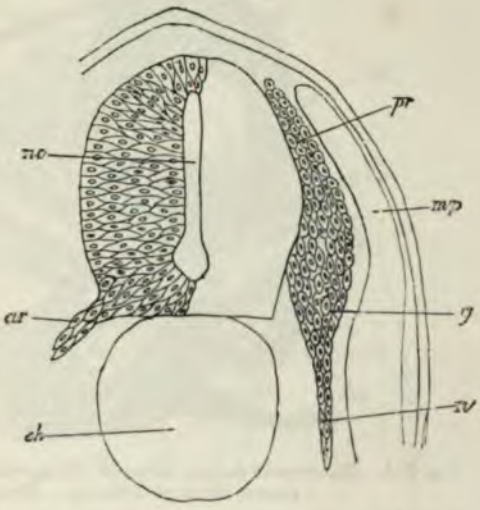


Fig. 743.—SECTION THROUGH THE DORSAL PART OF THE TRUNK OF A TORPEDO EMBRYO. (From Balfour.)

pr, posterior root of spinal nerve; *g*, spinal ganglion; *n*, nerve; *ar*, anterior root; *ch*, notochord; *nc*, neural canal; *mp*, muscle-plate.

The anterior roots of the spinal nerves are also outgrowths from the medullary wall. They begin to appear somewhat later than the posterior roots, as projections from its ventral side, and extending from thence outwards, come to join the nerve which emanates from the ganglion of the posterior root; and from this point the compound nerve grows towards the periphery or region of its distribution. The place at which the anterior roots spring from the spinal cord is not opposite to the corresponding posterior root, but midway between that root and the succeeding one. Both roots and ganglion have at first a cellular structure, and their fibres are of later origin, the cells being largest in the ganglion, and the fibres appearing earlier in the anterior than in the posterior roots.

Cranial Nerves.—Most of the cranial nerves, viz., the olfactory, the 3rd, 5th, and 7th, the auditory, the glossopharyngeal, and the vagus, arise from a neural crest in a manner analogous to the spinal posterior roots; and in the chick the ridge from which some of them spring is perceptible even before the closure of the medullary canal at its dorsal lip of inflection (Marshall); and as it is more immediately attached to the medullary than to the epidermal part of the epiblast, the cranial nerve-roots may be regarded as taking their origin from the rudimentary brain.

The cerebral neural crest is continuous with that of the spinal

marrow. It extends to the roof of the mid-brain, and there is the sam shifting downwards of the attachment of the roots to the neural cres as in the spinal nerves. In most of the nerves it has been observe that a subdivision occurs into portions representing a root, a ganglio and a peripheral nerve-trunk. The change of the place of attachmen is most remarkable in the case of the third nerve, which is carried dow quite to the lower surface of the mid-brain.

The sixth and the twelfth (or hypoglossal) nerves may arise, accordin to Marshall, as motor or lower roots of certain of the other nerves; bu

Fig. 744.

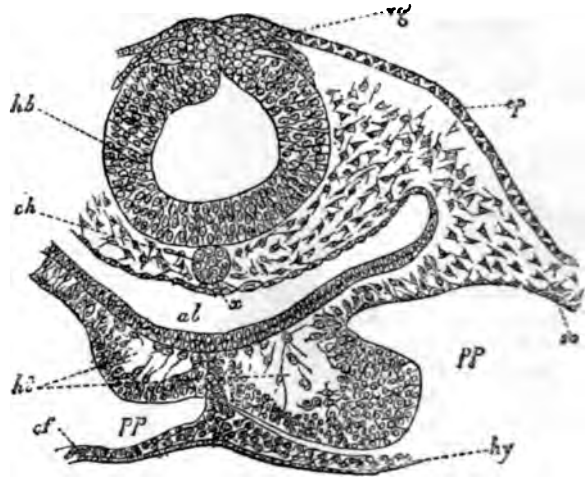


Fig. 744.—TRANSVERSE SECTION THROUGH THE POSTERIOR PART OF THE HEAD OF AN EMBRYO CHICK OF 30 HOURS. (From Balfour.)

hb, hind-brain; *vg*, vagus nerve; *ep*, epiblast; *ch*, notochord; *x*, sub-notochordal rod; *al*, throat; *ht*, heart; *pp*, body-cavity; *so*, parietal mesoblast; *sf*, visceral mesoblast; *hy*, hypoblast.

the mode of origin of these two nerves, as well as of the fourth, has no yet been fully ascertained, and Balfour doubts whether the cranial nerve before described as arising dorsally from a neural ridge or crest, are, lik the dorsal roots of the spinal nerves, exclusively sensory. Some of them he holds, are undoubtedly mixed, and all of them may be so. (No. 205

The olfactory nerve is certainly an outgrowth from the fore-brain: but wheth from an extension forwards of the neural crest or not is still doubtful. In t olfactory nerve of mammalian embryoes, A. Fraser has observed the root gangli and two main divisions of the nerve forking over the nasal pit (see fig. 745).

The origin of the Optic nerve and retina from the primitive medullary fo brain (as will be shown later) is different from that of all other nerves.

The fifth nerve, shortly after its origin in connection with a neural crest li the rest, undergoes the shifting change of position, and is united to the ro ment of the large Gasserian ganglion. Of its three principal branches t inferior maxillary belongs to the mandibular arch, in the hinder part of whi it is placed. Its ophthalmic and superior maxillary divisions are premandibul and according to Balfour probably belong to face-arches in that situation. T superior and inferior maxillary divisions fork over the cleft of the mouth, whi the ophthalmic branch is connected with the third nerve in the ciliary ganglio

The facial and auditory nerves appear to have a common origin. The main destination of the facial, as seen at an early period, is the hyoid arch, but it also sends forward a branch which is very large in young embryoes, forks over the hyo-mandibular cleft, and joins the inferior maxillary of the fifth in the mandibular arch as the chorda tympani of mammals. Besides this, two other branches

Fig. 745.

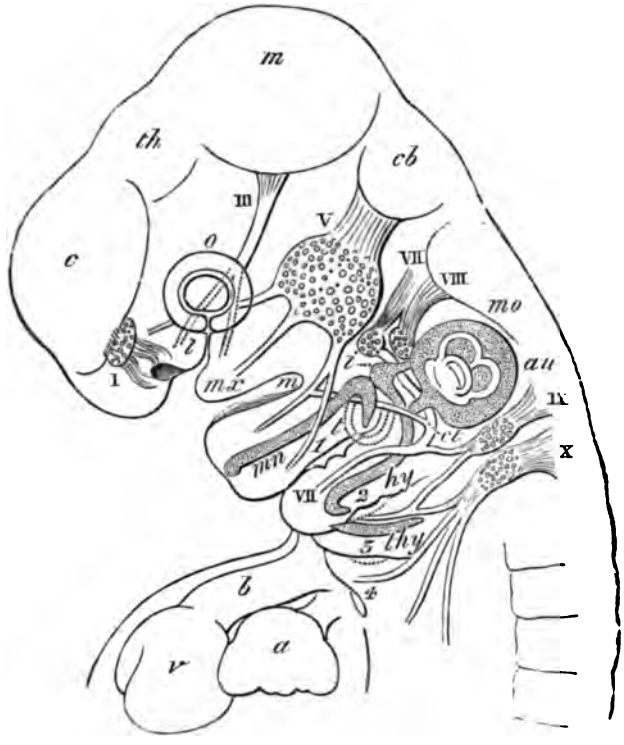


Fig. 745.—OUTLINE DIAGRAM OF THE HEAD OF A MAMMALIAN EMBRYO, CORRESPONDING TO A HUMAN EMBRYO OF EIGHT WEEKS, SHOWING THE RELATION OF SOME OF THE PRINCIPAL CRANIAL NERVES TO THE VISCERAL ARCHES AND THE DEVELOPMENT OF THE OSSICULA AUDITUS. (After A. Fraser, A.T.)

c, Cerebral hemispheres; *th*, thalamencephalon; *m*, midbrain; *cb*, cerebellum; *mo*, medulla oblongata; *o*, eye; *I*, olfactory ganglion and nerves passing to nasal cleft; *III*, third nerve; *V*, fifth nerve with Gasserian ganglion and its three branches; *VII*, facial nerve; *ct*, its chorda tympani branch; *VIII*, the auditory nerve; *IX*, glossopharyngeal nerve forking over the second postoral cleft; *X*, vagus; *l*, lachrymal cleft; *mx*, maxillary arch; *m*, mouth with indication of tongue; *mn*, mandibular cartilage with malleus forming in its proximal part; *i*, incus forming in the second cartilaginous arch; *t*, indication of the lower part of tympanic ring; *au*, the auditory capsule, semicircular canals, &c.; *hy*, hyoidean cartilage; *thy*, thyro-hyoidean cartilage; 1, 2, 3 and 4, indicate the places of the postoral clefts which are now closed; *b*, aortic bulb; *v*, ventricles of the heart; *a*, left auricle.

proceed forward from the facial, which are proportionally large in the embryo, viz., the superficial ophthalmic and the palatine (or superficial petrosal), which are respectively associated with the ophthalmic and superior maxillary divisions of the fifth nerve.

The auditory nerve, which proceeds at once to join the labyrinth of the ear, has a ganglion developed upon it at a very early period.

The glosso-pharyngeal nerve is connected with the third visceral or first true branchial arch, and in the lower vertebrates the pneumo-gastric or vagus is distributed to this and the branchial arches which follow in whatever number they may be. These nerves have in the chick a common origin from the dorsal neural crest of the after-brain, but, like the other nerves previously mentioned, they afterwards shift downwards so as to be placed on the sides.

According to Balfour some of the cranial nerves, such as the third, fifth and facial, besides the glossopharyngeal and vagus, may be held to bear definite relations to mesoblastic somites or muscle plates of the head, each being placed immediately behind the head-cavity of its respective somite. As stated by Parker, this relation is the following. Each of these nerves divides or forks above a visceral cleft, one division going to the posterior face of the arch in front of the cleft, the other to the anterior face of the arch behind it.

Fig 746.

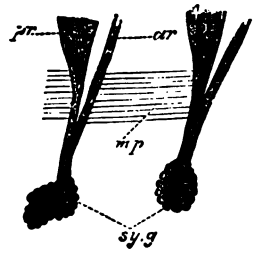


Fig. 746.—LONGITUDINAL VERTICAL SECTION THROUGH PART OF THE BODY-WALL OF AN ELASMOBRANCH EMBRYO SHOWING TWO SPINAL NERVES AND THE SYMPATHETIC GANGLIA BELONGING TO THEM. (From Balfour.)

ar, anterior root; *pr*, posterior root; *sy.g*, sympathetic ganglion; *mp*, part of muscular plate.

The orbito-nasal and the palatine divisions of the trigeminus belong to an anterior arch, the former above, the latter below the optic nerve. The superior maxillary division follows the palato-pterygoid arch, the inferior maxillary nerve accompanies the mandibular arch.

The facial nerve divides above the hyo-mandibular cleft, its anterior part (chorda tympani) going to the posterior side of the mandibular arch, and its posterior part to the outer or anterior side of the hyoid arch.

The glosso-pharyngeal nerve, by a similar division, goes by its anterior branch to the posterior side of the hyoid arch, and by its other division to the front of the first branchial or thyro-hyoid arch.

In the higher animals the pneumo-gastric nerve shows no close relation to the clefts, but in branchiate vertebrates it forks over the remaining gill clefts and supplies branches to the gill arches.

Sympathetic Nerves.—It has been ascertained by Balfour that the sympathetic ganglia and nerves arise in connection with the gangliated roots of the cranial and spinal nerves, and they may therefore be regarded as springing from the same neuro-epiblastic source. This fact has been confirmed for birds and mammals by Schenk and Birdsell (No. 207).

The gangliated cord of the sympathetic has been described and figured by Kölliker in the human fœtus of eight or ten lines long. The peripheral sympathetic nerves are also formed at a very early period, and are perceptible in a fœtus of three months.

The Suprarenal Bodies.—The belief of a relation subsisting between the suprarenal bodies and the sympathetic ganglia of the nervous system seems to have originated with Bergmann in 1839, and to have received confirmation on embryological grounds from Remak in 1847, who called these bodies "nerve glands." It has, in fact, been long known that they have not any connection either by their origin or their permanent structural relations with the Wolffian bodies or with the kidneys. Leydig showed (1853) that in the adult plagiostomes, ganoids and reptiles the organs which represent the suprarenal bodies of the higher animals consist of

two separate sets of parts, of which one is intimately associated with the sympathetic ganglia and contains ganglionic cells, while the other is of a different nature. Kölliker's observations in the human embryo (No. 28, i. p. 618) gave further support to the view of the nervous nature and origin of these bodies; and more recently the researches of Balfour in elasmobranchs, Braun in reptiles and Brunn in birds, have led the first of these authors to state confidently the general view that while in elasmobranchs and some others of the lower vertebrates (No. 32, Vol. II. pp. 548–9) the suprarenal bodies consist of two distinct parts, viz., one median and single which he proposes to call "interrenal" of mesoblastic origin, and the other paired and derived from the sympathetic ganglia, in the amniota these two sets of parts are combined in the paired organs which constitute the compound suprarenal bodies. The development of these two sets of parts is, however, distinct; that derived from the mesoblast being converted into the cortical part, and the substance which proceeds from the ganglia being enclosed within the first in the course of their development.

The development of the suprarenal bodies of mammalia has very recently been made the subject of investigation by Mitsukuri (No. 212) in the rabbit and rat, the result of which fully confirms Balfour's views, and shows that in these animals the medullary part of the suprarenal bodies arises by development from the sympathetic ganglia of the abdomen lying below the aorta, that the cortical substance is of a totally different nature and of mesoblastic origin, and that the two sets of parts are gradually combined in the course of their formation. The medullary or nervous substance is at first situated outside the cortical or mesoblastic element, but gradually insinuates itself into the interior, retaining, however, some connection with the neighbouring ganglia. In the lower vertebrates, as already stated, this combination has not taken place, the two components of the suprarenal bodies remaining distinct and separate.

III. PRINCIPAL ORGANS OF SENSE:

I. THE EYE.

Primary Development.—The embryonic structures forming the eyeball and its contents may be considered as proceeding from three sources, viz., 1st, by evolution or expansion from the medullary wall of the thalamencephalon, giving rise to the retina in its nervous and pigmental structure and to the optic nerve; 2nd, by involution and development of a part of the cuticular epiblast, forming the foundation of the lens and the epithelium of the conjunctiva; and 3rd, by the intrusion of mesoblastic elements between and around the other parts, so as to furnish the materials out of which are formed the external coverings of the eyeball, cornea and sclerotic, the fibrous and vascular choroid, the ciliary apparatus and iris, the capsule of the lens and the capsulo-pupillary membrane, the vitreous humour, and all the fibrous and vascular parts of the organ.

The very early formation of the *primary optic vesicles* has been already mentioned, p. 823. The bulging wall of the anterior primary vesicle which is thus projected outwards on each side gives rise, by the subsequent folding and changes which occur in it, to the nervous part of the eye, viz., the retina and optic nerve, together with the pigmental layer which comes to lie external to the retina. This folding takes place simultaneously with the development of the crystalline lens, which is the product of an involution of the cuticle or epiblast occurring on the outside of each primary optic vesicle. During the involution and enlargement of the lens, the wall of the primary optic vesicle comes to be depressed and doubled in upon itself, so as to form a cup-like hollow towards the exterior, the secondary optic vesicle, into which the lens is received, but without filling entirely its cavity. The outer plate or involuted portion of this cup or secondary optic vesicle becomes by

its further development and histological differentiation the nervous pa of the retina, while the remaining inner or proximal plate is convert into its pigmental layer, and the stalk becomes the optic nerve in co nection with the brain.

Fig. 747. Fig. 748.

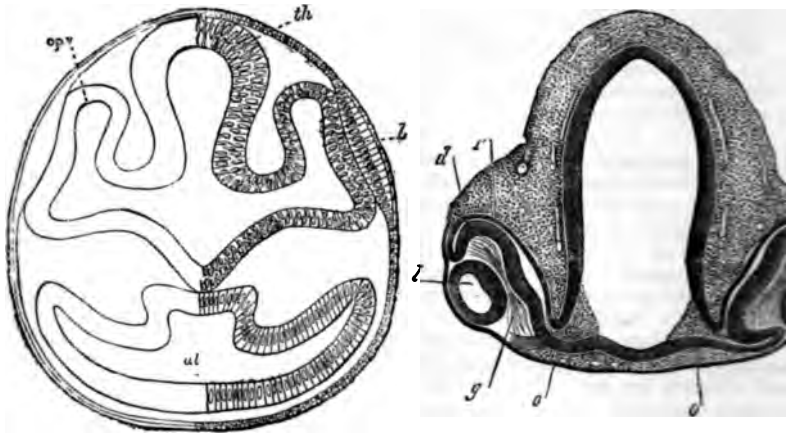


Fig. 747.—Section through the front part of the head of a Lepidosteus embry (From Balfour.)

al, alimentary tract; *th*, thalamencephalon; *l*, lens of the eye; *op.v*, the optic vesicle

Fig. 748.—Frontal section through the head of an embryo chick of 3 days and 6 hours. (From Kölliker.) ♀

o, stalk of the ocular vesicle in connection with the thalamencephalon; *p*, proxim and *d*, distal wall of secondary ocular vesicle; *l*, lens; *g*, vitreous body.

The transition at the line of inflection from the thick nervous part t the thin pigmental part is quite sudden, and as soon as pigment cell begin to be developed a very marked distinction is perceptible betwee the latter and the nervous structure of the retina. These cells wer

Fig. 749.

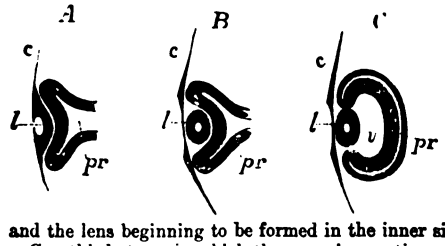


Fig. 749.—Section of the com mencing eye of an embryo f three stages. (From Remak.)

A, commencement of the forma tion of the lens *l*, by depression of part of C, the corneous layer; *pr* the primitive ocular vesicle no doubled back on itself by the de pression of the commencing lens.

B, the lens depression enclose and the lens beginning to be formed in the inner side, the optic vesicle more folded back

C, a third stage, in which the secondary optic vesicle, *v*, begins to be formed.

formerly regarded as a part of the choroid membrane, but they are now looked upon as belonging rather to the retina,—a view which is fully warranted by the mode of development now described.

The fold which produces the optic cup proceeds from above down wards, and surrounds the lens so as to appear to enclose it, but leave

for a time an aperture or depression below. This is the *choroidal fold* or fissure, which may easily be distinguished in the embryo-head after pigment has been deposited, from the circumstance that the pigment is absent from the cleft, which thus appears for a time as a broad white line, particularly obvious in the embryo bird, running from the circumference in upon the lens.

Fig. 750.

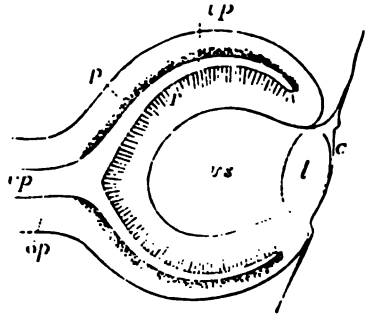


Fig. 750.—DIAGRAMMATIC SKETCH OF A VERTICAL LONGITUDINAL SECTION THROUGH THE EYEBALL OF A HUMAN FŒTUS OF FOUR WEEKS. (After Kölliker.) $\frac{100}{1}$.

The section is a little to the side so as to avoid passing through the ocular cleft. *c*, the cuticle, where it later covers the cornea; *l*, the lens; *op*, optic nerve formed by the pedicle of the primary optic vesicle; *vp*, primary medullary cavity of the optic vesicle; *p*, the pigment-layer of the outer-wall; *r*, the inner wall forming the retina; *vs*, secondary optic vesicle containing the rudiment of the vitreous humour.

The lens is developed in the part of the cuticle opposite to the most projecting part of the primary optic vesicle, or at the place where this vesicle comes in contact with the surface of the head. In this situation there is seen from a very early period a thickening of the epiblast, which seems to reside chiefly in its deeper layer of cells, and in birds and mammals it would appear that an actual involution of the cuticle takes

Fig. 751.

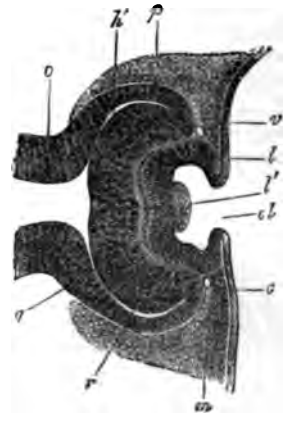


Fig. 751.—HORIZONTAL SECTION THROUGH THE EYE OF AN EMBRYO RABBIT OF TWELVE DAYS AND SIX HOURS. $\frac{75}{1}$. (From Kölliker.)

o, stalk of the ocular vesicle with wide cavity; *h'*, remains of the cavity of the primitive ocular vesicle; *p*, proximal lamella of the secondary vesicle (pigmentum nigrum); *r*, distal lamella (retina); *g*, vitreous body; *l*, lens vesicle, widely open at *ol*; *l'*, papillar elevation in the bottom of the lens vesicle which forms the lens; *m*, with *v*, an annular vessel at the anterior border of the secondary vesicle; *e*, epiblast.

place, so that first an open follicle and next an enclosed ball of cuticle is formed. Although, however, both the corneous and the deeper layer (sensory of Stricker) of the cuticle are enclosed, it is only the cells of the deeper layer which undergo development into the fibres of the lens. The external cuticle separating from the ball of the lens, passes freely over its surface, and a cavity filled with loose cells exists for a time within the lens. Then the cells of the hinder or inner wall are seen to rise from the bottom by their elongation, and thus a rapid growth of fibres from that side of the lens takes place, while the anterior or outer wall undergoes no similar change, but retains its simply cellular structure. Figures 751 and 752 show sufficiently clearly the manner in which the fibres thus

developed from cells rise from the bottom of the lens ball and come to constitute its solid part.

The optic cup receives the enlarging lens in its anterior and lower opening, and the reflected margins of the cup closely embrace the margin of the lens; but there soon comes to be a considerable space intervening between the lens and the hollow of the optic cup (or secondary vesicle), which is later occupied by the vitreous humour. Into this space

Fig. 752.

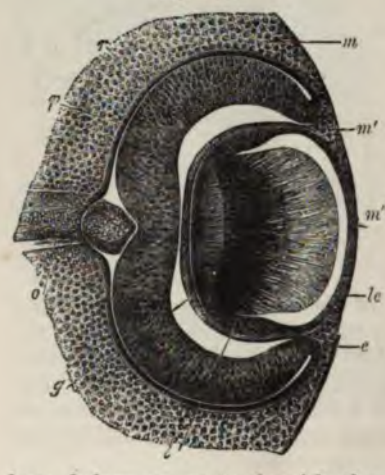


Fig. 752.—Eye of an embryo rabbit of 14 days; horizontal section. $\frac{6}{1}$. (From Kölliker.)

o, optic nerve; *p*, pigmentum nigrum; *r*, retina; *g*, vitreous body, which by its contraction has left a space behind it; *l*, posterior thick wall of the lens vesicle, or rudiment of the lens; *le* anterior thin wall or lens epithelium and between them the hollow of the lens vesicle; *m*, mesoderm surrounding the secondary ocular vesicle, no sclerotic or choroid yet formed; *m'*, connection of this with the vitreous body; *m''* thin layer of mesoderm in front of the lens or rudiment of the cornea and pupillary membrane; *e*, portion of the epithelium of the front of the eye.

connective tissue and blood-vessels developed from mesoblastic elements are projected from below, so as to furnish the materials for the formation of the vitreous humour and the blood-vessels which pass through it to the lens, and also to surround the lens with vascular and fibrous elements, out of which are produced the *capsulo-pupillary membrane*, and probably also the capsule of the lens. It results from the observations of Lieberkühn (No. 216) that in mammals the fold which produces the ocular cup or secondary vesicle runs back into the stalk so as to fold in the optic nerve for a considerable space, and by the simultaneous enclosure

Fig. 753.

Fig. 753.—Transverse vertical section of the eyeball of a human embryo of four weeks. (From Kölliker). $\frac{100}{1}$.

The anterior half of the section is represented. *pr*, the remains of the cavity of the primary optic vesicle; *p*, the inflected part of the outer layer forming the retinal pigment; *r*, the thickened inner part giving rise to the columnar and other structures of the retina; *v*, the commencing vitreous humour within the secondary optic vesicle; *v'*, the ocular cleft through which the loop of the central blood-vessel, *a*, projects from below; *l*, the lens with a central cavity.

of mesoblastic tissue thus to lead to the introduction of the central blood-vessels of the retina within the nerve. But in birds, according to the same observer, no such infolding of the stalk occurs, so that in them the vessels are excluded from the nerve. The malformation termed *colobom*

iridis is to be attributed to a persistence of the choroidal cleft, and the pecten of birds, close to the optic nerve, with the vascular fold farther forwards, and the falciform fold of the eyes of fishes are to be regarded as fibro-vascular structures formed by original projection through the same interval.

The **further development** of the parts of the eye may be briefly stated as follows:—

The expansion of the ocular cup continuing to proceed, the chamber for the vitreous humour enlarges, and that structure gradually comes to occupy the space between the retina and the lens.

Fig. 754.

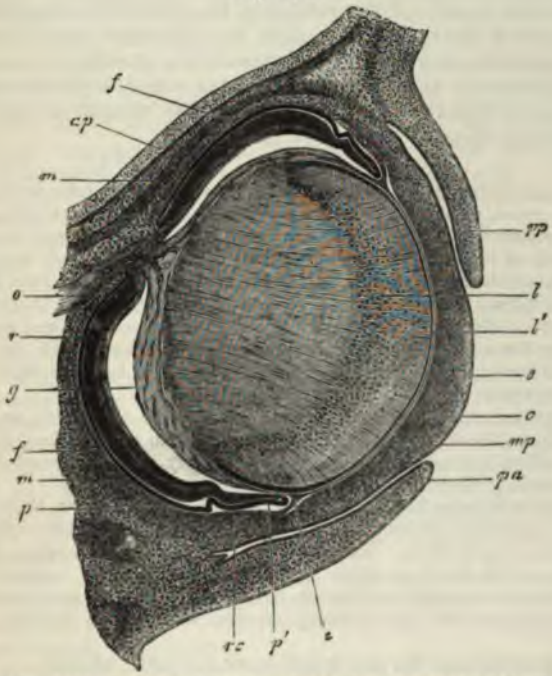


Fig. 754.—HORIZONTAL SECTION THROUGH THE EYE OF AN EMBRYO RABBIT OF 18 DAYS. $\frac{3}{1}$. (From Kölliker.)

o, optic nerve; *ap*, ala parva; *p*, pigmentum nigrum; *r*, retina; *rc*, ciliary part of the retina; *p'*, forepart of the secondary ocular vesicle or rudiment of the iris pigment; *g*, vitreous body raised from the retina by shrinking, except where the vessels from the centralis retinæ enter it; *i*, iris; *mp*, membrana pupillaris; *c*, cornea with epithelium *e*; *pp*. *pa*, palpebræ; *l*, lens; *l'*, lens epithelium; *f*, sclerotic; *m*, recti muscles.

The marked distinction between the nervous and the pigmental portions of the primitive ocular vesicle goes on increasing by the continued deposit of pigment in the latter, and its proportional thinning, and by the great addition to the thickness and the textural differentiation of the substance of the former. Thus the cells in the retinal or nervous portion, by their rapid multiplication, soon become several layers thick; certain of these cells assume the spindle shape, and exhibit elonga-

tion into fibres, while others retain the nuclear form, and thus there is foreshadowed the division into the fibrous, ganglionic, and nuclear layers of the retina. On the exterior a limiting membrane makes its appearance, and in connection with it the rudiments of the cells composing the layer of rods and cones. The space between the retinal and pigmental layers rapidly contracts, and finally the rods and cones are closely united with the layer of pigment cells.

The optic nerve, as already described, is at first connected by its origin with the vesicle of the third ventricle or thalamencephalon, and for a time it retains its earlier hollow form. But as the cerebral hemispheres are developed forwards, the eye and the optic nerve are thrown backwards and downwards, and a new connection is established between the optic nerve (or tract) and the vesicle of the mid-brain (mesencephalon): the rudiment of the optic commissure is at the same time formed by the median approximation of the stalks and the growth of one over the other. Each stalk then becomes more and more solid by the development of nerve fibres and the formation of the sheath substance of the nerve from the enclosed connective tissue.

Retina and Optic Nerve.—The full development of the minute nervous structures of the eye is a subject of great difficulty, and observers are not quite agreed as to its phenomena. The rods and cones are undoubtedly formed in connection with the cells of the outer granular layer, but their outer and inner limbs are probably formed from different cells, the membrana limitans externa being at an early period placed between. According to Kölliker the layer of ganglion cells and the inner molecular layer are the first to be differentiated, and are very soon followed by the nerve fibres which spread over the interior of the retina. A somewhat different account of the process is given by Löwe (No. 222*), to whose work we must refer the reader.

At the ora serrata the denser nervous structure of the retina ceases, and in front of this, as far as the inflection of the distal into the proximal or pigmental layer, the retina is continued as the thinner ciliary portion, bounded externally by the pigment of the ciliary processes.

It has generally been held, and it is still the opinion of some, that the pedicle of the optic vesicle is converted into the optic nerve by the differentiation of its substance into nerve fibres. But a different view has been taken by His and by Kölliker (No. 28, i. p. 690) according to which the original substance of the pedicle is supposed to furnish only the supporting structures, and the nerve fibres are formed by secondary emanation from the chiasma or nervous centre.

According to Kölliker the yellow spot is not yet visible at birth.

Lens.—The development of fibres from the hinder wall of the primitive lens-follicle continuing to take place, the cavity of the follicle is first greatly narrowed and then completely filled up by the lengthening fibres, and the lens takes more and more of its full spherical shape. The new fibres continue to be formed towards the margin of the lens; each fibre retaining its nucleus, so as to produce the *nuclear zone* which runs through the whole lens. This zone is at first situated far back in the lens while the fibres are still short, but as they elongate its place is advanced, so that it comes to be situated considerably in front of the equatorial plane of the lens. It is most distinct towards the margin where the fibres are newly formed. The anterior wall of the lens-follicle remains as a simple cellular layer. The greater number of the fibres now follow the general curve of the surface of the lens, presenting therefore their concavity towards its centre, but the curvature gradually diminishes in those nearest the middle, where they are straight, or nearly so. Only the external short and recently formed fibres present a concavity towards the exterior. The intersecting stars of the anterior and posterior poles of the lens now make their appearance by the collection of cells in the peculiarly shaped triradiate or multiradiate space in these

two situations, and the ends of the fibres are now traceable to the edges of these spaces, so that the fibres gradually take the arrangement round the poles of the lens which belongs to the adult.

The origin of the capsule of the lens appears to be still somewhat doubtful. Lieberkühn, Arnold and Löwe profess to trace it to a thin pellicle of mesoblast which at an early period passes in between the lens and the secondary ocular vesicle; but Kölliker and Kessler are of opinion that it is a cuticular deposit on the surface of the lens cells. Balfour is inclined to adopt the latter view, on the ground that the capsule seems to make its appearance before the introduction of the mesoblast has occurred.

The *fibro-vascular structures* of the eye, which are all derived from mesoblastic elements, either surrounding the secondary ocular vesicle or passing into it by the choroidal fissure, may be considered as consisting of three sets of parts, viz., 1st, that which is external to the ocular cup and which becomes the sclerotic, the cellular substance of the cornea and also the choroid membrane; 2nd, that which occupies the interior of the optic cup, and which becomes the vitreous humour, and the capsulo-pupillary membrane with the arteria centralis retinæ; and 3rd, that which is developed in the angle of meeting of the two parts previously mentioned, *i.e.*, between the margin of the lens and the reflection of the two layers of the optic cup, and in which the ciliary processes, ciliary muscle and iris are mainly formed. The pigmental elements which any of these parts possess are derived from that of the retina or proximal wall of the optic cup.

Cornea.—The formation of the cornea is mainly due to a differentiation of the tissue in the layer of mesoblast which is interposed between the primitive lens-follicle and the corneous epiblast. The layer forming the cornea is at first very thin, and quite homogeneous, and it has been doubted if this is mesoblastic; soon, however, the corneal cells, proceeding from mesoblast which advances from the margin, penetrate the homogeneous layer, and gradually progress towards the centre, greatly thickening it, and dividing it into layers. The original homogeneous substance which is left free of cells at its margins constitutes the outer and inner elastic layers. Within these is the cellular layer of the membrane of Descemet, which comes from a different source. There is at first no aqueous chamber in the eye, and even after the solution of continuity which gives rise to this space has occurred, the cavity is not dilated with fluid, till near the time of birth. Even then it is very shallow and the lens is placed close to the cornea, in the greater part of its surface. The cavity of the aqueous humour arises by the separation of the cornea from a layer of the mesoblastic tissue lying within it. The latter gives rise to the anterior part of the vascular capsulo-pupillary membrane.

Sclerotic Coat.—The outer covering of the eyeball is formed from mesoblastic cells surrounding the ocular cup, and is probably continuous with the structure which furnishes the corneal cells, but it is only later that the cornea and sclerotic come to be completely amalgamated.

Choroid membrane.—The mesoblastic substance which surrounds the ocular vesicle externally is the source of important parts. Among these may be mentioned first the choroid membrane, the cellular (membrana fusca), fibrous, and vascular layers of which are developed out of the deeper division of the mesoblastic substance, and to the same source may be traced the ciliary processes, ciliary muscle and iris; while the zonula ciliaris may be regarded as a part of the deeper mesoblastic tissue connected with the formation of the hyaloid membrane and membrana capsulo-pupillaris.

The **capsulo-pupillary membrane,** already referred to, may be looked upon as at first a complete fibro-vascular investment of the lens, which owes its origin to the deepest part of the enclosed mesoblast. The vessels of this membrane are supplied by a branch of the central artery of the retina, which passes forwards in the axis of the globe, and breaks up at the back of the lens into a brush of rapidly subdividing twigs. The forepart of this tunic, adherent to the pupillary margin of the iris, forms the *pupillary membrane* by which the aperture of the pupil is closed in the middle periods of fœtal life. In the human eye, the whole tunic, together with the artery which supplies its vessels, becomes atrophied and is lost sight of before birth, but in some animals it remains apparent for a few days

after birth. According to Kölliker, the anterior chamber expands only a short time before birth by the intervention of the aqueous humour between the iris and cornea.

Fig. 755.

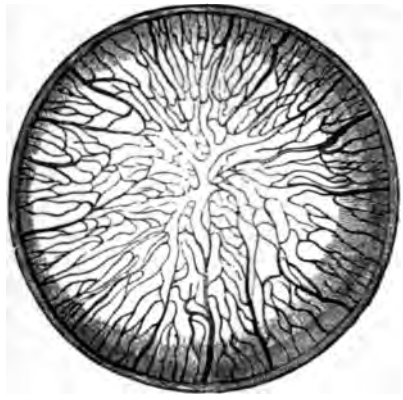


Fig. 755.—Blood-vessels of the capsulo-pupillary membrane of a newborn kitten, magnified. (From Kölliker.)

The drawing is taken from a preparation injected by Tiersch, and shows in the central part the convergence of the network of vessels towards the centre of the pupillary membrane.

The iris is developed from a proliferation of mesoblastic tissue which takes place in the angle between the anterior reflection of the walls of the ocular cup and the margin of the lens and cornea, and it is intimately connected with the capsulo-pupillary membrane, with which, indeed, it appears to be continuous anteriorly. It is thus in relation with all the fibro-vascular structures of the eye. It derives its pigmental layer from a reduplication of the anterior part of the pigmental layer of the ocular cup. It does not acquire free surfaces till after the formation of the aqueous chamber.

The ciliary muscle is developed in the mesoblastic tissue between the base of the iris and the ciliary processes of the choroid membrane.

Vitreous Humour and Hyaloid Membrane.—These parts are usually regarded as being derived from the intruded mesoblast; but while this may be true of the vitreous humour and the blood vessels which pass through it to the back of the lens, there are grounds for believing the hyaloid membrane to be derived by circular exfoliation from the ocular cup. The zonule of Zinn probably belongs to the same set of parts.

The **eyelids** make their appearance gradually as folds of integument, subsequently to the formation of the globe in the third month of fœtal life. When they have met together in front of the eye, their edges become closely glued together by an epithelial exudation which is removed a short time before birth.

The **lachrymal canal** may be regarded as a persistently open part of the fissure between the lateral nasal process and the maxillary lobe of the embryo.

The first discovery of the mode of development of the eye as it is now generally understood was made by Huschke in 1832, and was published in Meckel's Archiv. for that year. In addition to the systematic works on Development, the reader is referred to the special treatises mentioned in the Bibliography.

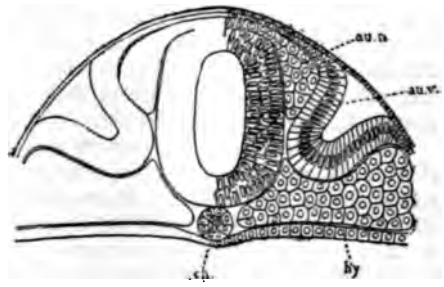
II. THE EAR.

Primary Development.—The most important part of the organ of hearing originates by the involution of the epiblast from the external surface of the head in the region of the medulla oblongata. This is at first only a depression of a thickened part of the epiblast; but the depression soon deepening, and, its aperture towards the surface rapidly narrowing, it assumes a flask-like form, and constitutes on each side the primary auditory or otic vesicle.

This involution of the auditory vesicle takes place somewhat later than the evolution of the medullary vesicle of the eye, and differs from it in taking place secondarily from the epiblastic surface of the head.

nd not in immediate connection with the brain. The auditory vesicle is tuated opposite the dorsal end of the hyoidean arch. The original

Fig. 756.



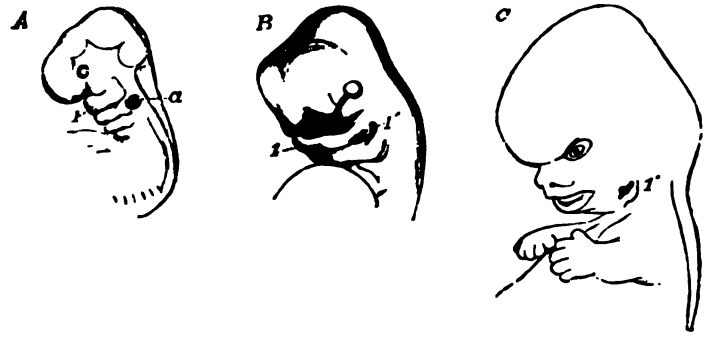
g. 756.—Section through the head of a Lepidosteus embryo of an early period. (From Balfour.)

au.v, auditory vesicle ; *au.n*, ditory nerve ; *ch*, the notochord, mediately below the medulla oblongata ; *hy*, hypoblast. The nervus layer of the epiblast is seen to distinct from the cuticular layer hich is not involuted.

perture, which is directed ackwards, is soon closed externally, but in the interior vestige of it remains for a considerable time as the *recessus labyrinthi*, hich corresponds to the aqueduct of the vestibule of later life.

The primary otic vesicle, sinking down towards the basis of the ranium, becomes imbedded in the formative mesoblastic tissue lying etween the basi-occipital and alisphenoid matrices, and along with them ndergoes chondrification and ossification at an early period, as has been lready described under the development of the head.

Fig. 757.



g. 757.—Outlines showing the early changes in the form of the head of the human embryo.

A, profile view of the head and fore part of the body of an embryo of about four weeks rom nature, $\frac{10}{1}$) : the five primary divisions of the brain are shown, together with the rimary olfactory and optic depressions, and *a*, the auditory vesicle ; 1, marks the mandibular plate, and behind this are seen the three following plates with the corresponding aryngeal clefts. *B*, from an embryo of about six weeks (from Ecker, $\frac{4}{1}$) : the cerebral misphere have become enlarged and begin to spread laterally ; 1, the lower jaw ; 1′, e first pharyngeal cleft, now widening at the dorsal end, where it forms the meatus ternus ; the second cleft is still visible, but the third and fourth clefts are closed and e corresponding arches have nearly disappeared. *C*, from a human fœtus of nine weeks rom nature, $\frac{4}{1}$) ; the features of the face are now roughly formed ; the outer part of the st pharyngeal cleft is now undergoing conversion into the meatus, and the auricle is ginning to rise at its external border.

The development of the organ of hearing, as a whole, consists of two ery different sets of processes, viz., 1st, those connected with the

formation of the nervous structure or labyrinth of the internal ear, a
2nd, those belonging to the development of the tympano-Eustachi
passages and the accessory parts of the middle and outer ear. The fi
of these sets of changes occurs more immediately in the primary epiblas
vesicle in combination with the nervous elements derived from t
medullary centre, and with the participation of the mesoblastic wall
the auditory capsule. In the second are involved the remarkable trar
formations of the first visceral arch and the hyomandibular cleft.
describing these changes reference will be made chiefly to mammals.

Labyrinth.—After the closure of the primary otic vesicle the exte
sion of its cavity in different directions soon indicates the formation
the different parts of the future labyrinth. As the otic vesicle sin
more deeply into the base of the cranial wall, from being at first spheri
it takes more of a pyriform shape, the pointed prolongation of the recess
labyrinthi stretching backwards or dorsally towards the place of t
original involution from the surface.

Fig. 758.

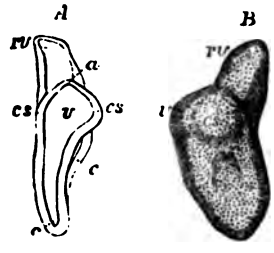


Fig. 758.—LABYRINTH OF THE HUMAN FŒTUS FOUR WEEKS, MAGNIFIED. (From Kölliker.)

A, from behind; B, from before; *v*, the vestibul *rv*, recessus labyrinthi, giving rise later to the aqued of the vestibule; *cs*, commencement of the semicirc canals; *a*, upper dilatation, belonging perhaps to other semicircular canal; *c*, cochlea.

This narrower part soon becomes tub
lar, and stretches into the cranial wall, whi
it pierces, and in which, as the aqueda
of the vestibule, it becomes enclosed at
later period in the substance of the petrous bone. In elasmobranc
fishes it remains open to the surface throughout life.

The auditory vesicle is also soon prolonged into an angular projecti
at its lower or ventral end, where it forms the commencement of th
cochlear part of the labyrinth.

The two superior semicircular canals next appear as elongated elevati
of the surface of the primary vesicle; the middle portion of each ele
tion becomes separated from the rest of the vesicle by the bending in
the walls under it, and thus the elevation is converted into a tube remai
ing open at both ends, which subsequently becomes elongated and acqui
an ampullar dilatation; and while the cochlear extension continues
progress, and takes the form of a canal curving inwards, the exter
or horizontal semicircular canal begins to be formed much in the sam
manner as the two superior ones.

These changes are followed by a marked constriction of the main pa
of the vesicle on its inner side near the cochlear canal, which, gradual
increasing, at last completely cuts off the part which afterwards becom
the *saccule* from the remaining larger portion which forms the *utric*
A constriction also takes place in the vesicular wall between the saccul
and the cochlear canal, leaving, however, these two cavities in commun
cation by the narrow *canalis reuniens*.

The same constriction which separated the saccule and utricle leads t
the division of the end of the recessus labyrinthi into two tubes, one o
which now opens into each of these cavities.

The anterior or ventral part of the membranous labyrinth which is to form the foundation of the cochlea in mammals becomes soon elongated into a tube which is gradually bent inwards and coiled upon itself from

Fig. 759.

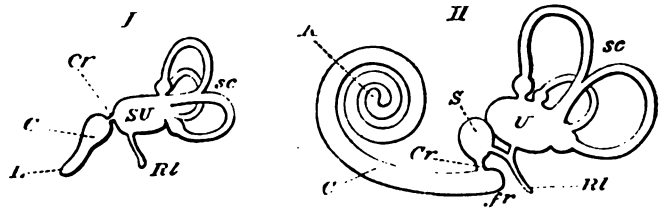


Fig. 759.—Diagrams of the membranous labyrinth (after Gegenbaur.)

I, in a bird; II, in mammals; *sc*, semicircular canals; U, utricle; S, saccule; (SU. combined in I); *Rl*, recessus labyrinthi; *Cr*, canalis reuniens; C, cochlea; *fr*, its commencement at fenestra rotunda; K, cupola; L (in I) lagena.

left to right, at last to the extent of two and a half turns, and on the hollow side of this spiral there is now formed a double ridge of thickened epithelium which at a later stage is converted into the organ of Corti and the structures connected with the lamina spiralis.

Fig. 760.

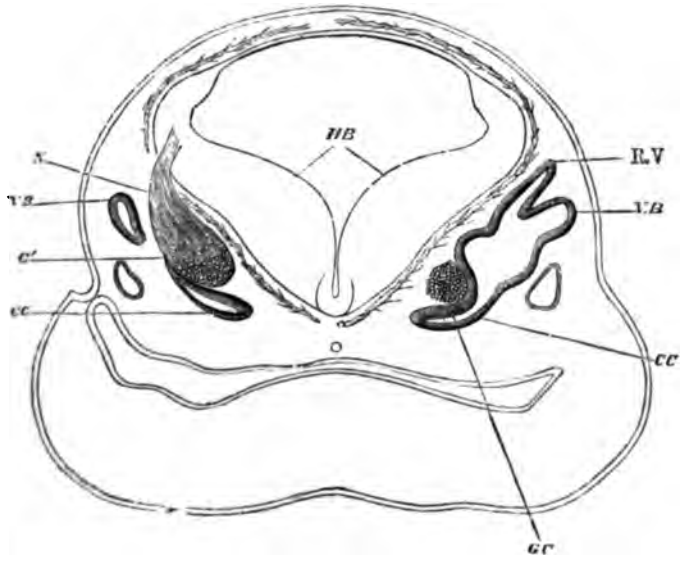


Fig. 760.—Transverse and slightly oblique section of the head of a foetal sheep, in the region of the hind brain (from Foster and Balfour after Boettcher.)

HB, inner surface of the thickened walls of the hind brain; RV, recessus vestibuli; V.B commencing vertical semicircular canal; CC, canalis cochleæ, with the cavity of the ditive otic vesicle. On the left side parts only of these structures are seen; GC, ... ganglion of the right side; on the left side, G', the ganglion, and N, the ... connected with the hind brain.

Meanwhile, however, it may be mentioned that the deposit of cartilage has advanced rapidly in the auditory capsule surrounding the vesicle, and this is soon followed by ossification of the capsule, as elsewhere stated. But between the cartilaginous wall and the various parts of the membranous labyrinth mesoblastic tissue has been interposed which gives rise to the periosteum and to the lymph spaces which surround the membranous labyrinth and contain the fluid termed perilymph, while the various inflections of the labyrinthic cavity which are of epiblastic origin are filled with the endolymph.

Fig. 761.

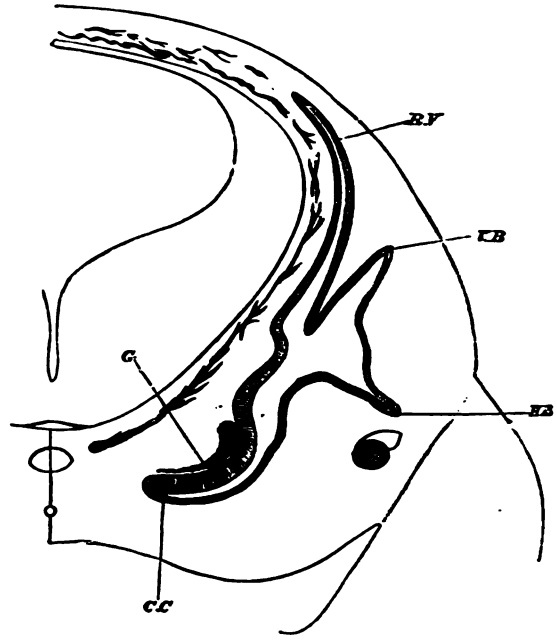


Fig. 761.—Transverse section of the head of a fœtal sheep of four-fifths of an inch in length. (From Foster and Balfour after Boettcher.)

RV, recessus vestibuli; VB, vertical semicircular canal; CC, cochlear canal; G, cochlear ganglion; HB, horizontal canal.

In the cochlea these spaces also exist, but in the special form of two tubular prolongations, one of which is situated on each side (above and below) of the cochlear canal, representing the first form of the scala vestibuli and scala tympani. Of these lymph passages the upper communicates with the vestibule, but the lower or scala tympani, which is somewhat later in being formed, is closed at the fenestra rotunda. The scalæ gradually progress along the coils of the cochlear canal till they reach its summit or *cupola*, which at first adheres to the wall of the capsule. From this, however, it is afterwards separated, when the two scalæ, having arrived at the summit, communicate with each other and intervene between the cupola and capsular wall.

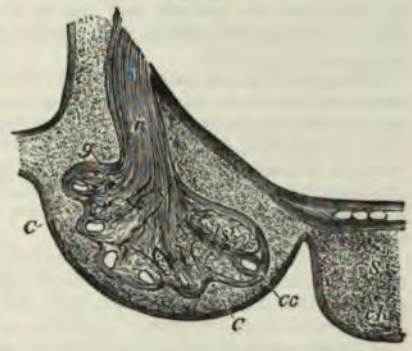
The *lagena* of the uncoiled cochlea of birds corresponds to the cupola of the cochlear canal in mammals.

The lamina spiralis, with the organ of Corti and the upper and lower separating membranes (membrane of Reissner and membrana basilaris), are

Fig. 762. — TRANSVERSE SECTION OF THE COCHLEA IN A FŒTAL CALF, MAGNIFIED. (From Kölliker.)

C, the wall of the cochlea, still cartilaginous; *cc*, canalis cochleæ; *ls*, placed in the tissue occupying the place of the scala vestibuli, indicates the lamina spiralis; *n*, the central cochlear nerve; *g*, the place of the spiral ganglion; S, the body of the sphenoid; *ch*, remains of chorda dorsalis.

Fig. 762.



afterwards gradually developed outwards from the central pillar of the coiled cochlea; but we cannot attempt to give any detailed account of the formation of these minute and intricate structures.

It may, however, be mentioned that the auditory nerve when first formed is of large size and pierces the auditory capsule in two main divisions, vestibular and cochlear. The latter is remarkable as having upon it at an early period a large ganglion which exists before the cochlea becomes coiled, but which, being developed along with the lamina spiralis, takes the same coiled form (see fig. 761, and p. 466 of this volume).

The modiolus and spiral lamina, according to Kölliker, are ossified without the intervention of cartilage.

Accessory Parts of the Organ of Hearing.—The remarkable combination of the internal ear, or labyrinth, with certain other parts, to form the middle and external divisions of the acoustic apparatus, has already been adverted to in the account of the development of the face. Here, without going over the whole subject, we shall have only to refer shortly to some points of morphological interest connected with it.

The **tympano-Eustachian** passage is generally held, according to the view first propounded by Huschke, and confirmed by Reichert and others, to be developed in connection with the inner part of the hyo-mandibular or first postoral visceral cleft, while the meatus externus and pinna, or auricle, are formed on the outside; the membrana tympani, with its tympanic ring being interposed between, and the chain of ossicula with their accessory parts being formed in close relation with them. There can be no doubt that this view is substantially correct. But more recent researches, besides giving greater precision to the facts, have also modified in some degree the history of the process. From these researches it appears that the tympanic ring and the membrana tympani are developed close to the external surface, and that the meatus is therefore formed more immediately in connection with the outer skin, and by outward growth of the parts surrounding it, rather than by any actual depression.

Further, it is ascertained by the observations of A. Fraser that the hyo-mandibular cleft is from an early period almost completely closed in its dorsal portion by the intervention of the membrana tympani. This membrane consists of a layer of epiblast externally, of pharyngeal hypoblast internally, and, between these, of its fibrous and vascular parts, which are of mesoblastic origin.

According to the same author (No. 230), the malleus, as now agreed

by all, is developed from the proximal part of the mandibular cartilage. and by observations on a variety of mammals he has shown that the incus is formed, according to the view advocated by Huxley and Parker, and contrary to that of Reichert, Salensky and others, in the proximal part of the hyoidean cartilage, which, from the first, is in close proximity to the mandibular cartilage. Fraser has further shown, in corroboration and extension of Salensky's observations (No. 229), that the stapes does not arise as a part of the hyoidean cartilage or as a bud from the periotic wall, but as a circular deposit of cartilaginous cells round the stapedial artery, near to the fenestra ovalis, with which its base is afterwards connected.

With respect to the precise mode in which the tympanic cavity and Eustachian canal are formed in relation with the hyo-mandibular cleft, some difference of opinion has arisen among recent observers. Some, as Moldenhauer and Huss (Nos. 222 and 228), have brought forward the view that these parts of the auditory passages are one or both of them new outgrowths from the pharynx, and others (Urbantschitsch), that they proceed from the mouth. But these authors do not give sufficient grounds for departing from the generally accepted opinion on the subject.

The pinna is gradually developed in connection with the integument on the posterior margin of the first visceral cleft. It is deserving of notice that congenital malformation of the external ear, with occlusion of the meatus and greater or less imperfection of the tympanic apparatus, are observed in connection with abnormal development of the deeper parts of the first and second visceral arches and the intermediate cleft (Allen Thomson. No. 231).

III. THE NOSE.

The organ of smelling, as was first pointed out by v. Baer, owes its origin, like the primary auditory vesicle and the crystalline lens of the eye, to a depression of the epiblast, and it differs from these involutions in remaining permanently open and in being greatly extended as a complicated cavity communicating with the exterior.

It has already been shown how closely the development of the nose is connected with, first, the extension of the axial part (trabeculæ) of the basi-facial axis; second, the formation of the mouth, so that a part of the common cavity comes to be separated by the palate plates into the true buccal and lower nasal cavities; and, third, more superficially and in front, with the external nasal wall.

The olfactory organ arises in all vertebrates at a very early period of embryonic life in the form of a depression of thickened epiblast from the forepart of the head.

The whole of the nasal fossæ, however complicated they may become in the labyrinthic form which they afterwards assume in many animals, are due to the involution of the epiblast of the original olfactory pits; and the structure of the parts forming these inflections, as well as those associated with them, which are derived from mesoblastic sources, may be considered as essentially the same in different animals. In man these structures do not attain any great degree of complexity in the olfactory part, but in the human nose, as in animals, there is a marked difference in the form of that part of the labyrinth on which the olfactory nerve is distributed, and in the minute structure of its epithelium, from those of the lower part which forms the respiratory passage of the nose.

There is at first no olfactory lobe of the brain, and the nerve is solid. Marshall has shown that the olfactory lobe is formed at a comparatively late period, as at the end of the seventh day in the chick, and that this lobe arises by extension of the wall of the forebrain at the place

where the nerves have previously sprouted out; that it contains a hollow prolonged from the general ventricular cavity, and carries the nerves on its most projecting part.

The development of the olfactory nerve has already been described.

III. DEVELOPMENT OF THE BLOOD-VASCULAR SYSTEM.

General Phenomena.—The heart and blood-vessels, with the blood-corpuscles and fluid, which from the first occupy their interior, take their origin entirely from the mesoblast, and the earlier rudiments of these

Fig. 763.

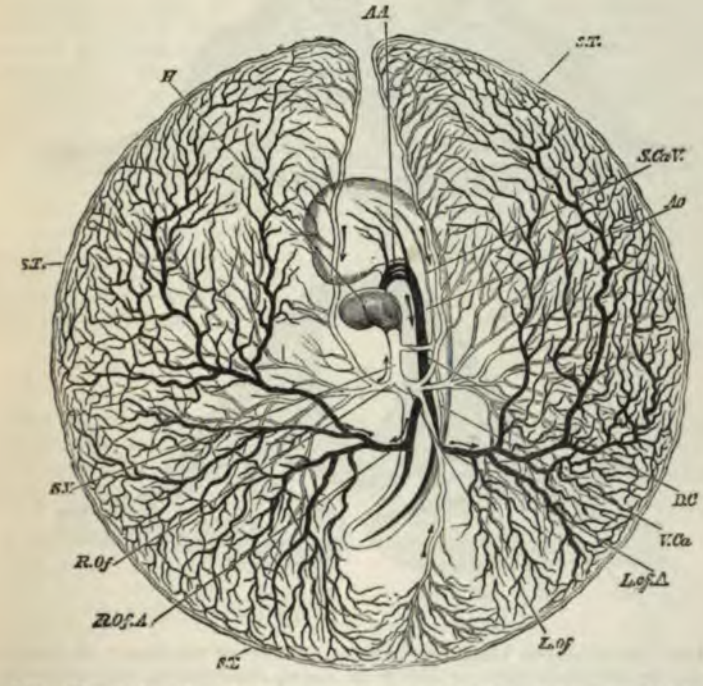


Fig. 763.—Vascular area of the yolk-sac of the chick on the third day of incubation, seen from below. Magnified about six diameters. (From Balfour.)

H, heart; *AA*, three of the aortic arches of one side; connected with the uppermost are the external and internal carotid arteries; *AO*, dorsal aorta; *L.of.A*, left vitelline artery; *R.Of.A*, right; *S.T.*, Sinus terminalis; *L.Of*, left vitelline vein; *R.Of*, right; *S.V.*, sinus venosus; *D.C*, Ductus Cuvieri; *S.Ca.V*, superior cardinal vein; *V.Ca*, inferior; the arteries are shaded black, the veins are in outline; the embryo seen from its lower or left side is only faintly indicated.

vascular elements are situated in the deepest part of the visceral plate of the mesoblast, which was thence distinguished by Pander as the vascular layer of the blastoderm. At a later period it is probable that blood-vessels may arise throughout the whole of the mesoblast, both in its visceral and parietal divisions.

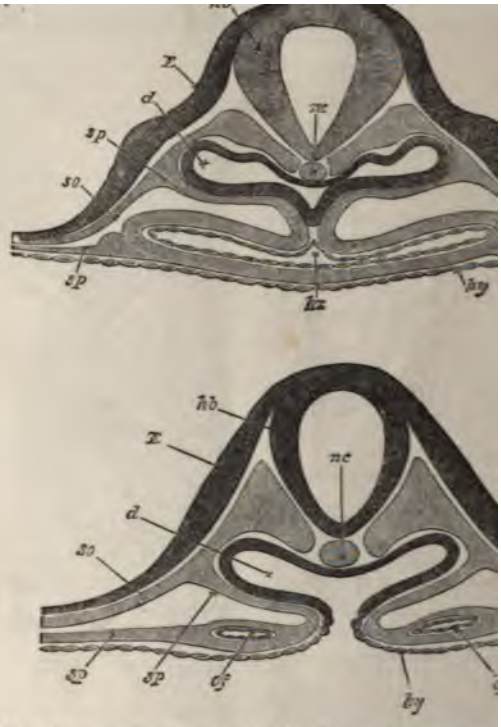


Fig. 764.—Diagrammatic views of two sections through
brain of an embryo-chick of about 36 hours, illusti
the heart. (From Balfour.)

In A, which is farthest forward, the parts of the hea

to prove that the process is essentially the same in them all. The earlier steps of this process follow one another very rapidly, so that already by the 40th or 42nd hour in the fowl's egg the blood is propelled through the primary system of vessels by the rhythmic contractions of the tubular and as yet only cellular heart. At this period the parts of this very simple circulatory system consist of the blood fluid containing corpuscles in a rudimentary form; of blood-vessels, which are mainly spread over the vascular area and in less number within the body of the embryo; and of a median tubular heart, into which the blood is brought from behind by two veins which collect it from the vascular area, and from which it is expelled anteriorly by two outgoing vessels which may be called arteries, though they do not as yet show any of the histological characters of these vessels.

The minuter steps of this process have been so fully described in the histological part of this work (p. 34 and p. 197), that it is unnecessary to do more at this place than to recall the fact that the blood-fluid and corpuscles originate by a change in the formative cells of the visceral mesoblast, which is accompanied by a differentiation of their protoplasm and multiplication of nuclei within spaces developed by internal vacuolization of the mesoblastic cells. The cells which give rise to the primary blood-vessels becoming hollow and radiated, and their processes being united together, capillary networks are produced by their dilatation into tubes and their intercommunication. The demarcation of the limits between the epithelial cells forming the walls of the primary capillary vessels is a later process, as also the addition of the cellular materials for the production of the middle and outer coats, and other tissues which give a more complex structure to the larger vessels: but nearly all the vessels consist at first only of endovascular elements, and have much of the form and structure of capillaries.

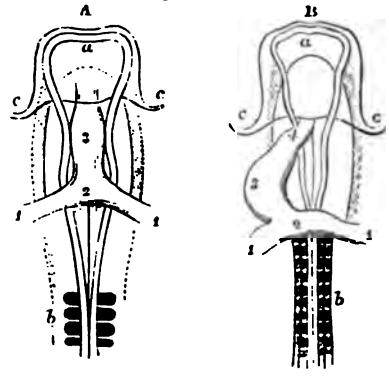
I. THE HEART.

The origin of the heart itself is in some respects histologically similar to that of the vessels, in so far that it is by the vacuolated formation of one or of two main tubular spaces within groups of mesoblastic cells that the cavity of the organ originates (see fig. 744, p. 838). But the formation

Fig. 765.—Outlines of the anterior half of the embryo chick viewed from below, showing the heart in its earlier stages of formation. (After Remak.) ♀

A, embryo of about 28 to 30 hours; B, of about 36 to 40 hours; *a*, anterior cerebral vesicle; *b*, proto-vertebral segments; *c*, cephalic fold; 1, 1, vitelline or omphalo-mesenteric veins entering the heart posteriorly; 2, their union in the auricle of the heart; 3, the middle part of the tube corresponding to the ventricle; 4 (in B) the arterial bulb.

Fig. 765.



of the walls of the primitive heart is due, not merely to the accumulation and differentiation of the mesoblastic cells in the region which it at first occupies, but is also effected by a folding of the mesoblastic layers round the cavity. In these folds two sets of

cells are distinguishable from a very early period, viz., 1, those of a more delicate character and looser disposition in which the space or spaces for the heart's cavity are more immediately formed, and which afterwards range themselves round that cavity in the form of an endocardiac lining, and, 2, those forming a thicker layer which undergoes inflection, and which give rise to the muscular part of

Fig. 766. Fig. 767.

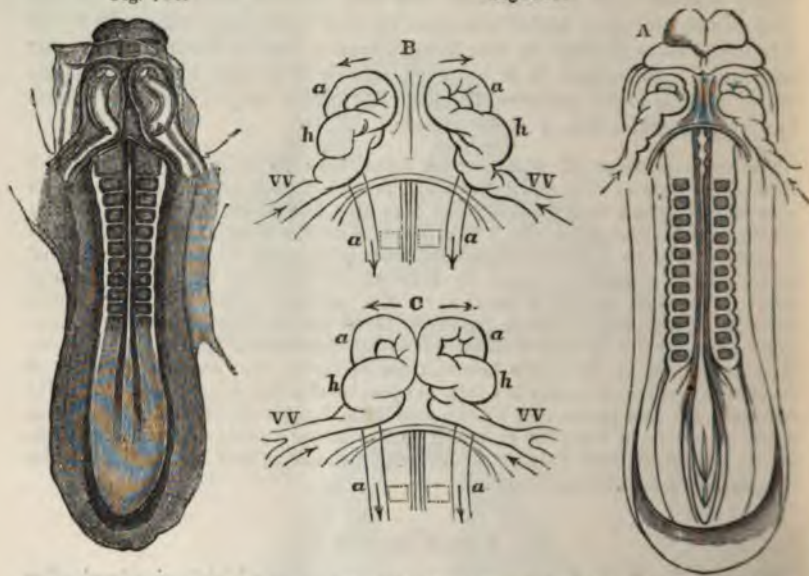


Fig. 766.—Embryo rabbit of eight days and eighteen hours, viewed from the ventral aspect. $\frac{8}{1}$. (From Kölliker.)

In the anterior part of the ventral wall on each side there is seen the separate rudiment of the heart, in the simple vascular tube of which are to be distinguished the hinder auricular, the middle ventricular and the anterior bulbous parts. There are ten proto-vertebral segments.

Fig. 767.—Views from below of the embryo-rabbit of nine days and three hours, showing the commencing heart in two stages. $\frac{8}{1}$. (A. T.)

These sketches, of which B and C are partly diagrammatic, were taken from two preparations given me by Professor Kölliker. A is the view from below of one of the embryoes in which the formation of the heart was least advanced, and of which an outline of the heart, &c., is repeated in B. In C, taken from the second preparation, the two halves of the heart are seen in the commencement of their coalescence. *h*, the part of the bent tube which becomes the ventricle; *a*, primitive aortic arches and separate descending aortas; VV, the vitelline veins entering the heart posteriorly. The arrows indicate the course of the blood.

the wall. The pericardial covering arises by an extension of the wall of the body cavity which folds itself round each side of the commencing part of the heart.

There is, however, a considerable difference among animals in the form presented by the rudiments of the primitive heart, connected apparently with a difference in the rate of progress of the cephalic fold of the blastoderm which incloses the anterior part of the alimentary canal, and the median coalescence of the parts which give rise to the

heart itself. Thus in certain animals, such as elasmobranchs, cyclostomata, ganoids, and amphibia, in which the closure of the cephalic fold is rapid, the deeper or endocardiac rudiments of the heart are collected into a mesial mass, and the cavity of the organ hollowed out in their interior is from the first single, and occupies a place on the ventral side of the pharynx immediately behind the branchial arches,

Fig. 768.

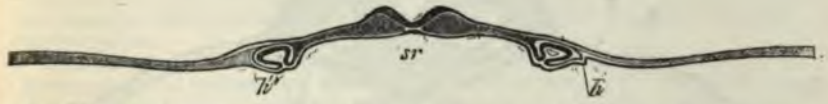


Fig. 768.—TRANSVERSE SECTION THROUGH THE HEAD OF AN EMBRYO RABBIT OF EIGHT DAYS AND FOURTEEN HOURS, WITH A PART OF THE PERIPHERAL BLASTODERM. $\frac{45}{1}$. (From Kölliker.)

hh, rudiments of the heart; *sr*, pharyngeal groove.

where it receives the inflection of the mesoblastic cells, which form its muscular wall. But in others, such as mammals, in which the fact was first discovered by Hensen (No. 88), in osseous fishes, and to some extent also in birds, in which the enclosure of the pharyngeal cavity by the inflection of the cephalic fold is of later occurrence, the heart has at first the remarkable form of two tubes separated to some distance from each other, and the formation of the single and median cavity of the heart is due to the gradual approximation of these tubes and their coalescence

Fig. 769.

Fig. 769.—PART OF THE FOREGOING FIGURE MORE HIGHLY MAGNIFIED. $\frac{180}{1}$. (From Kölliker.)

rf, medullary groove; *rw*, dorsal ridge; *mp*, medullary plate and rudiment of the brain; *h*, epiblast; *hp*, parietal wall; *dfp*, visceral mesoblast, inflected into the outer wall of the heart *ahh*; *ihh*, inner or endovascular lining of the heart; *ph*, pericardial cavity; *mes*, mesoblast beyond the rudiments of the heart; *dd*, hypoblast; *dd'*, notochord; *sw*, lateral wall of the developing pharynx.

into one by the union and subsequent disappearance of the adjacent parts of their primitive walls. In the case of the heart being thus at first double, each tube receives posteriorly the large entering vein, and is prolonged anteriorly into the issuing vessel or artery; while in the median single heart, whether formed originally so, or by later fusion of two tubes, the posterior part receives the two entering veins, while the anterior part opens into the two primitive outgoing arteries.

The accompanying figures (768 & 769) from Kölliker will explain by sectional view the manner in which in mammals the inflection of the two laminæ of the meso blast gives rise to the walls of the separate compartments

Fig. 770.

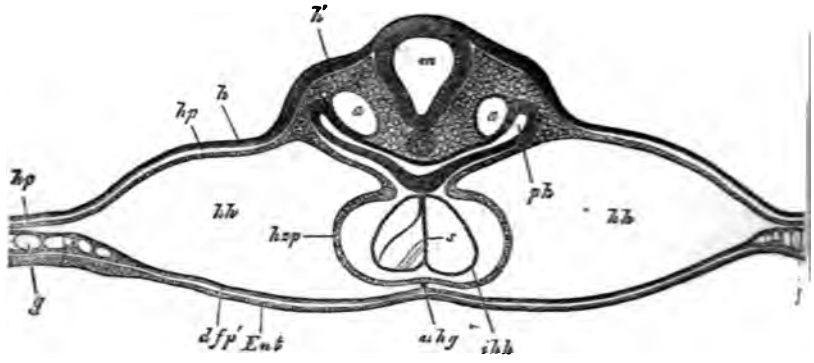


Fig. 770.—TRANSVERSE SECTION THROUGH THE REGION OF THE HEART IN AN EMBRYO CHICK OF 39 HOURS. $\frac{90}{1}$. (From Kölliker.)

m, medulla oblongata; *a*, *a*, descending aortas; *ph*, pharynx; *h*, epiblast: *h'*, thickening of the same where the auditory vesicle is to be formed; *hp*, parietal mesoblast: *hzp*, outer wall of the heart; *ihh*, inner wall, the cavity still divided by a septum: *hh*, pericardial cavity; *uhg*, ventral mesocardium produced temporarily by the reflection of the visceral mesoblast *hzp* into *dfp'*; *g*, *g*, vessels in the visceral mesoblast; *Ent*, hypoblast.

of the heart and the primary right and left compartments of the pericardium. The endocardiac lining (*ihh*) is derived from the deeper part of the visceral mesoblast.

Fig. 771.

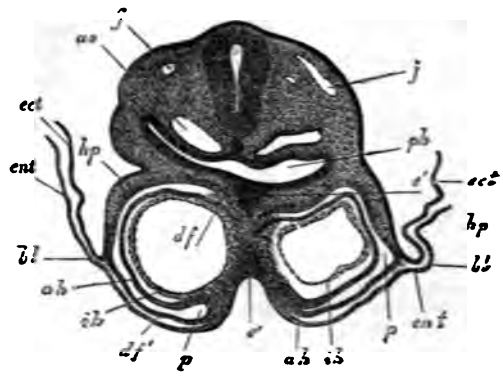


Fig. 771.—TRANSVERSE SECTION THROUGH THE REGION OF THE HEART IN A RABBIT'S EMBRYO OF FIVE DAYS. $\frac{90}{1}$. (From Kölliker.)

jj, jugular veins; *aa*, descending aortic roots: *ph*, pharynx; *hp*, body-wall reflected in *ect*; *ih*, inner cellular lining of the still divided heart; *ah*, outer wall of the heart; *p*, pericardial cavity; *df*, *df'*, visceral mesoblast: *c'*, prolongation of the hypoblast of the foregut and the anterior wall of the pericardial cavity into the partition between the two halves of the heart; *bl*, blastoderm; *ent*, visceral wall.

It would appear that in both forms of the heart's origin the inflection of the mesoblast which gives rise to its wall is at first incomplete. In the case of the single and median formation this has the effect of leaving the endocardiac wall of the rudimentary organ in immediate contact with the hypoblast of the cephalic part of the alimentary cavity; but very soon the further inflection of the

outer mesoblastic layer of cells completes the muscular and pericardial wall superiorly or on the dorsal side, leaving however there for a time a short septum at the place of meeting which constitutes a superior or dorsal mesocardium, while a similar septum exists for a time below as a ventral mesocardium.

The mode of formation of the heart in birds is in some degree intermediate between the two previously referred to, as the single organ arises by the coalescence of two tubes which are at first separate, but by the time these are formed the ventral wall of the pharynx is already advanced in its enclosure, so that it is almost impossible to detect the double form in the view of flat specimens of the bird's embryo. Hence, before the fact was ascertained by means of sections, the older observers all held the heart of the bird to originate as a single median organ.

The primitive veins or large vessels by which blood is carried into the posterior extremity of the rudimentary heart are the principal returning venous channels which collect the blood from the terminal sinus of the vascular area, while the two vessels which proceed from the anterior extremity form the first pair of aortic arches which bend over the side of the pharyngeal wall at the level of the mandibular arch and pass on dorsally in the body of the embryo below the vertebral somites as the two primitive aortæ, which afterwards coalesce to form the median aorta. To these further reference will be made later.

Among the further changes which the heart undergoes in the course of its progress from the simple form of a median symmetrical tube into

Fig. 772.

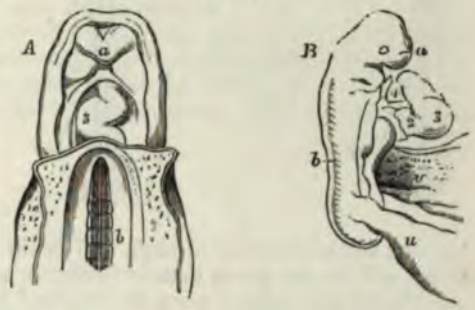


Fig. 772. — HUMAN EMBRYOS AT DIFFERENT EARLY STAGES OF DEVELOPMENT, SHOWING THE HEART IN ITS TUBULAR CONDITION.

A, upper half of the body of a human embryo of three weeks, viewed from the abdominal side (from Coste); *a*, frontal plate; *b*, protovertebræ, on which the primitive aortæ are lying; 3, the middle of the tube of the heart, below it the place of entrance of the great veins, above it the aortic bulb.

B, lateral view of a human embryo more advanced than that last referred to (from A. Thomson); *a*, the frontal part of the head; *b*, the vertebral column; *v*, the wide communication of the umbilical vesicle with the intestine; *u*, allantoic pedicle; 2, auricular part of the heart connected with the veins posteriorly; 3, ventricular part of the bent tube; 4, the aortic bulb; near the extremities of the tube the divided pericardium is seen.

its fuller state of development, one of the earliest may be attributed to the mere elongation of the tube, for the anterior and posterior extremities being fixed by the vascular connection to the body of the embryo, the elongating intervening part, which is not so attached, is necessarily thrown into a folded or curved shape, the middle part bulging ventrally, and taking usually a direction to the right side of the still prone and symmetrical embryo. This form of the heart has been observed in the human embryo of three weeks, corresponding in all respects to the heart of the bird or mammal at a parallel stage of advancement (see Fig. 772, A and B).

As the development of the tubular heart progresses, the bend increases, and the venous is doubled back upon the arterial end. The

tube also becomes divided by two slight constrictions into three portions, of which that originally posterior and receiving the veins is the widest, and constitutes the primitive auricle; the middle one, next in width, and most strongly bent upon itself, becomes the ventricular portion; and the third, situated anteriorly and retaining most the simple tubular form, is the arterial or aortic bulb.

Division into Single Auricle, Ventricle, and Arterial Bulb.—By a continued increase of the inflection of the heart-tube, a change in the relative position of the several parts is effected, so that the auricular cavity comes to be placed above or behind (dorsally) and to the

Fig. 773.

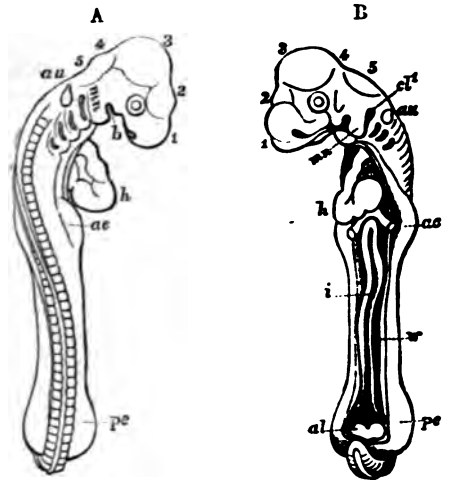


Fig. 773. — Outlines of the embryo of the chick at the end of the third day. ×. (After His.)

A, dorsal and right side; B, ventral and left side; h, the heart. The other parts of the figure are explained elsewhere.

left of the ventricular part, the veins being carried forwards along with it, while the arterial bulb is attached by its extremity in front to the neck of the embryo immediately below the visceral plates. There is as yet only a single passage through the heart, but the distinction of the auricular and ventricular cavities becomes more apparent, both by an increase in the diameter of each, and by the constriction which separates them, and by the much greater thickness acquired by the walls of the ventricular and bulbous parts as compared with the auricular portion.

The three parts of the heart have now the appearance of being very closely twisted together. The ventricular part becomes considerably wider transversely, and the auricular part shows two projecting pouches, one on each side of the arterial bulb, which are the first indications of the future auricular appendages. At the same time the constriction between the auricular and ventricular parts increases considerably, and the constricted part elongating, produces what has been called the *canalis auricularis*.

Division of the Right and Left Cavities. Ventricles.—The next series of changes in the developing heart consists in the division of each original single cavity of the ventricle, auricle, and arterial bulb into two compartments, so as to form the right and left ventricles and auricles, and the stems of the pulmonary artery and aorta. The first of these changes occurs in the ventricular portion, and is to be seen in progress on the fourth day in the chick, and in the sixth and seventh week in the human embryo. The ventricular chamber of the heart increasing considerably in breadth, that part of it which ultimately becomes the apex of the heart is thrown towards the left side, and in most mammals, and especially in

the human embryo, a blunt cleft or depression appears between this and the right part of the ventricle, which causes an external division into two portions corresponding to the future right and left ventricles; and if the interior of the ventricular cavity be examined at this time, there is perceived a crescentic partition rising from the lower border of the right wall and projecting into the cavity, at first narrow and placed opposite the external notch, but gradually growing more and more towards the

Fig. 774.—Head of the embryo of the dog with the heart seen from below. (From Kölliker, after Bischoff.) Magnified.

a, cerebral hemispheres; *b*, eyes; *c*, mid-brain; *d*, mandibular plates; *e*, superior maxillary processes; *f*, *f'*, *f''*, second, third, and fourth branchial or visceral plates; *g*, right, *h*, left auricle of the heart; *k*, right, *i*, left ventricle; *l*, aortic or arterial bulb, with three pairs of aortic or vascular arches proceeding from it.

Fig. 774.

auriculo-ventricular aperture. As development progresses the external division becomes more or less effaced, when the apex of the heart formed by the left ventricle becomes more pointed, and the whole heart takes somewhat of the conical form which belongs to its advanced condition; but in the adult heart the depression is still perceptible as the interventricular groove, which, as is well known, varies considerably in depth in different cases. In some animals, as the rabbit, the temporary external division of the ventricles is very apparent, while in others, as in

Fig. 775.

Fig. 775.—Shows the position and form of the heart in the human embryo from the fourth to the sixth week.

A, upper half of the body of a human embryo of nearly four weeks old (from Kölliker after Coste); B and C, anterior and posterior views of the heart of a human embryo of six weeks (from Kölliker after Ecker); *a*, frontal lappet; *b*, mouth; *c*, ventral ends of the second and third branchial arches; *d*, upper limb; *e*, liver; *f*, intestine cut short; 1, superior vena cava; 1', left superior cava or brachio-cephalic connected with the coronary vein; 1'', opening of the inferior vena cava; 2, 2', right and left auricles; 3, 3', right and left ventricles; 4, aortic bulb.

ruminants, there is very little of the external notching to be seen, and in them, as in birds, the heart very early assumes the conical form. The dugong presents a remarkable example of the persistence of the complete external separation of the ventricles, and in the seal a tendency has been observed to the occasional occurrence of the same variety (Ecker, A. Thomson).

The internal septum of the ventricles continuing to rise between the

right and left divisions of the cavity, reaches at last the base, where it is placed in relation with both the auriculo-ventricular orifice and the root of the arterial bulb; but at this place there remains for a time a communication over the still free border of the septum between the right and left ventricles, which is interesting, as this is the seat of the abnormal communication between the right and left ventricles in almost all cases of malformation of the heart presenting that condition.

Division of the Auricles.—Although the auricular cavity presents externally some appearance of being divided into two at a period antecedent to the partition of the ventricles, in consequence of the formation of the right and left auricular appendages before mentioned, the

Fig. 776.

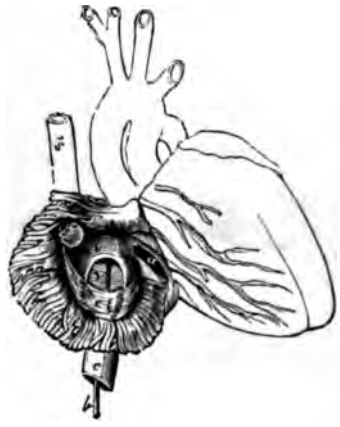


Fig. 777.

Fig. 776.—VIEW OF THE FRONT AND RIGHT SIDE OF THE FŒTAL HEART, AT FOUR MONTHS, THE RIGHT AURICLE BEING LAID OPEN. (From Kilian.)

a, the right auriculo-ventricular opening; *b*, a probe passed up the vena cava inferior and through the fossa ovalis and foramen ovale into the left auricle; *c*, vena cava inferior; *e*, Eustachian valve; *v*, valve of the foramen ovale; *s*, *s'*, vena cava superior.

Fig. 777.—VIEW OF THE POSTERIOR AND LEFT SURFACE OF THE HEART OF A FŒTUS OF FOUR MONTHS, THE LEFT AURICLE BEING OPENED. (From Kilian.)

a, left auricular-ventricular orifice; *c*, inferior vena cava, through which a probe *b*, is passed from below, and thence by the foramen ovale into the left auricle; *e*, left auricular appendage laid open; *o*, valve of the foramen ovale seen to be attached to the left side of the annulus ovalis of the septum.

internal division of the cavity does not take place till some time later, as on the fifth and sixth days in the chick, and in the eighth week in the human embryo. The auricular septum commences as an internal fold proceeding from the anterior wall of the common cavity, and starting from the septum of the ventricles, it grows backwards towards the entrance of the common vein or sinus, but stops short of it some distance. For a time, therefore, the veins enter the back part of the common auricular cavity. It is proper to explain, however, that, by the time at which the auricular septum is forming, the venous sinus has been ed so as to produce three veins entering the auricle at its back

part. Of these, two correspond to the permanent right superior and the inferior cava veins, and the third to a left superior cava connected with what afterwards becomes the coronary sinus. For a time, all the three vessels open so as to communicate freely with the whole auricular cavity. But changes now occur which cause the left superior cava and the inferior cava to be directed towards the left side, while the right superior cava is placed more immediately in connection with the right part of the auricular cavity.

The auricular septum, in extending itself backwards, is not completed, but leaves an oval deficiency in its lower and middle part, as the *foramen ovale*, and the inferior cava opens immediately behind this aperture. Some time later, or in the human embryo in the course of the tenth or eleventh week, two new folds make their appearance in the auricles posteriorly. One of these, constituting the *Eustachian valve*, of a crescentic form, is placed to the right of the entrance of the inferior vena cava, and in the angle between it and the orifice of the left superior cava (or great coronary sinus). This fold, besides separating these two veins, and thus throwing the opening of the left superior cava into exclusive communication with the right auricle, runs forward into the annulus ovalis or border of the anterior auricular septum, deepening the entrance of the inferior cava into a groove close to the foramen ovale, and thus directing the blood entering by that vessel through the foramen into the left auricle. (Kilian, 237).

The other fold referred to advances from the posterior wall of the common auricle to meet the anterior auricular septum, but to the left of the border of the foramen ovale. To this border, however, it adheres as it grows forwards, and thus gradually fills up the floor of the fossa ovalis. Up to the middle of fœtal life, this posterior septum being incomplete, there is a direct passage from right to left through the foramen; but, after that period, the fold in question, having advanced beyond the anterior border of the annulus ovalis and lying to the left, does not adhere to this or the fore part of the annulus, but leaves a passage between, and appears as a crescentic fold in the left auricle, which, as it passes beyond the annulus, constitutes in the last three or four months a very perfect valve against the return of blood from the left into the right auricle.

Division of the Arterial Bulb.—The third important change occurring in the heart belongs to the arterial bulb, by which there are developed from this tube the first parts or main stems of the pulmonary artery and the aorta. Within the thick walls of this arterial tube there is at first only a single subcylindrical cavity, continued from the originally single ventricle; but, soon after the partition of the ventricular cavity has commenced, or in the human embryo of the seventh week, a division of the bulb by an independent process begins to take place. This consists in the projection inwards from the distal end of the bulb of a fold of the wall, involving at first only the inner and middle coats, not perceptible externally, and advancing more rapidly on the two sides than in the middle. The cavity of the bulb is thus divided into two channels, which may be described as respectively anterior and posterior, but which, from the spiral direction taken by the folds, are somewhat twisted on each other, so that the channel which at the ventricular end is placed anteriorly becomes connected with the right ventricle and forms the pulmonary stem, and that which is placed posteriorly becomes

connected with the left ventricle and forms the commencement of the aorta. In the distal portion of the bulb, however, the pulmonary channel is situated to the left and posteriorly, and the aortic channel is to the right and most forwards; and at this end these channels are respectively connected with different aortic arches, giving rise to the permanent pulmonic and systemic vessels in the manner afterwards described. (Tonge, No. 248).

It is further to be noted that the partition of the bulb begins at the remote extremity between the fourth and fifth aortic arches, and advances towards the ventricles. There is a time, therefore, during which the ventricular septum, and the septum of the bulb, advancing towards each other, are incomplete and disunited; and from the difference in their general direction it is obvious that the septum of the bulb must be twisted upon itself, in order that it may finally unite and become continuous with that of the ventricles.

The completion of the partition of the aortic and pulmonary stems is afterwards effected by the progress of the division from within outwards through the external walls of the tubes; but the two vessels still remain united externally by a common envelope of pericardium.

The remarkable cases sometimes observed of abnormal transposition of the two great arterial stems from their natural connection with their respective ventricles may be explained by reference to the history of the development of the parts of the heart before given.

Formation of the Valves.—The formation of the auriculo-ventricular and semilunar valves takes place in the course of the second and third months in the human embryo. The semilunar valves of the aorta and pulmonary artery are formed simultaneously; and according to Tonge's observations in the chick, the plates or projections of the endocardiac lining which give rise to the valves are already formed before the septum of the bulb has reached the ventricle, and they arise at some distance from the ventricular orifices. The ventral and dorsal valves are the first to appear. Kölliker has observed these valves in the course of formation in the human embryo of seven weeks. The segments are at first of unequal size, one being much shorter than the other two. The sinuses are much later in being formed.

The auriculo-ventricular valves have been shown by the observations of Gegenbaur (No. 39), Bernays (No. 250), and Kölliker (No. 28, i.), to be formed out of plates which are originally part of the inner wall of the ventricles and auriculo-ventricular orifices. In connection with this it may be mentioned that the whole wall of the ventricles is in the earlier condition of the human heart, as in that of all animals, of a remarkable spongy or reticulated structure—a condition which remains persistent throughout life in most of the animals belonging to the three lower vertebrate classes: but in birds and mammals the reticulated structure is gradually lost by the solidification of the wall advancing from the outside inwards, and the columnæ carneæ and musculi papillares may be regarded as the vestiges of the reticulation internally.

The inner plates from which the auriculo-ventricular valves are formed contain at first a considerable amount of muscular substance, which afterwards in a great measure disappears.

In the latter changes, by which the inner plates are moulded into the form and structure of the valvular flaps, the upper or auricular part becomes fibrous, compact, and entire; the lower or ventricular part breaks up into the papillæ, which retain their muscularity and their attachment to the wall of the ventricles: while the intervening portion is more completely divided to form the thinner chordæ tendineæ in which the muscular structure is in a great measure or entirely lost. The division of the whole plates into the larger segments of the valves accompanies these changes.

The manner in which the pulmonary veins, which are formed separately in the lungs, come to be connected with the left auricle has not yet been ascertained.

No further important changes occur in the internal structure of the heart, but there are some which affect the external form and thickness of its walls. In early fœtal life the size of the heart bears a considerably greater proportion to that of the body than at a later period. At birth it is still proportionally large. For some time the auricular portion remains more voluminous than the ventricular, but in the latter half of fœtal life the permanent proportion is more nearly established. The walls of both ventricles are also thicker than in after life, and it is especially deserving of notice that the wall of the right is, up to near the time of birth, quite as thick as that of the left—a peculiarity which may be connected with the office of the right ventricle to propel the blood of the fœtus through the extended course of the ductus arteriosus, the descending aorta and the placental circulation.

II. DEVELOPMENT OF THE BLOOD-VESSELS.

The Principal Arteries. The Aorta.—The most interesting part of this history is that relating to the development of the aorta and the larger vessels arising from it.

In all vertebrates the arterial vessels proceeding from the ventral aortic bulb of the heart form five (and in some more) pairs of arches surrounding the anterior or pharyngeal part of the alimentary canal, and after a certain progress in development, uniting dorsally into the roots of the aorta of the trunk. At first, however, there is only one pair of these arches, and these are continued separately into the two vessels which represent the primitive state of the aorta.

It was first suggested by Serres, and subsequently proved by the writer of this chapter, by means of sections (No. 230, 1831), that the main aorta is formed by the median fusion of the two vessels previously separate. This fusion begins in the chick about the fortieth hour in the middle of the dorsal region, and extends forwards till it reaches the roots of the branchial arches, and backwards as far ultimately as the division into the iliac arteries. When this union reaches the place where the vitelline arteries pass out on each side, these vessels, each of which was previously the continuation merely of one of the primary main arteries, appear now as branches of a single and median aorta. The iliac are the next large vessels formed from the hinder part of the aorta. The first vessels belonging to these trunks are not, however, those of the lower limbs, for these do not yet exist; but rather the umbilical or hypogastric arteries, developed at a very early period in connection with the allantois, and subsequently attaining to a large size along with the growth of the placenta. As the limbs are formed, the arteries are developed in them which afterwards become the iliac divisions of the main aorta: but they are for a long time comparatively small, while the umbilical arteries are of very large size, so that, even up to the conclusion of fœtal life, these last appear to form the principal part of the two large vessels into which the aorta divides.

The relation of the process of mesial fusion of the originally double aorta to the occurrence of a permanent double canal in that vessel as a malformation,

described by Vrolik, Schröder van der Kolk, and Cruveilhier, and observed als by Allen Thomson, has already been referred to in vol. i., p. 350.

According to Serres, the vertebral arteries within the cranium are originally separate, and the basilar artery results from their mesial union or fusion in the same manner as occurs in the aorta; and the union of the two anterior cere

Fig. 778.

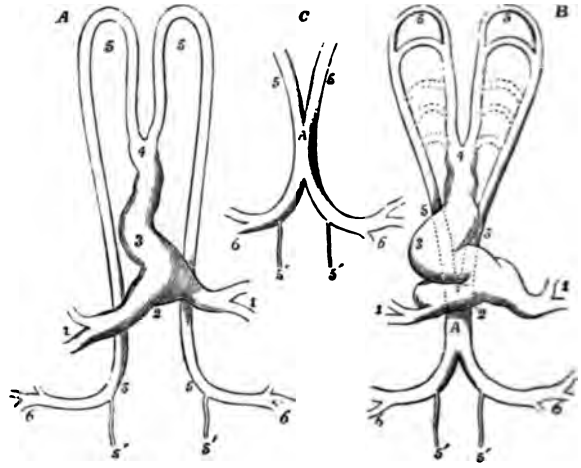


Fig. 778.—DIAGRAMMATIC OUTLINES OF THE HEART AND PRIMITIVE VESSELS OF THE EMBRYO CHICK AS SEEN FROM BELOW AND ENLARGED. (A. T.)

A, soon after the first establishment of the circulation; B, C, at a somewhat lat period; 1, 1, the veins returning from the vascular area; 2, 3, 4, the heart, now in th form of a notched tube; 5, 5 (upper), the two primitive aortic arches; 5, 5 (lower), th primitive double aorta; A, the single or united aorta; 5', 5', the continuation of th double aortæ beyond the origin of the large omphalo-mesenteric arteries, 6, 6. Th division above 4 is represented as carried rather too far down.

bral arteries in the forepart of the circle of Willis is another example of th same process. It seems probable that the internal cross band observed by Joh Davy in the interior of the basilar artery may be a remnant of the septum (united walls of the two vertebral arteries.

Aortic or Branchial Arches.—The two primitive arterial arch which lead into the dorsal aorta from the arterial bulb of the rudimenta heart, at the time of the establishment of the first circulation, are th most anterior of a series of five pairs of vascular arches which a developed in succession round this part of the pharynx; and whic since their discovery by Rathke in 1825 (No. 173), have been regarde with much interest, as corresponding with those which are the se of development of the subdivided blood-vessels of the gills in fishes an amphibia. These vascular arches thus exhibit in the amniota, alon with the branchial clefts and visceral arches, a typical resemblance to th structure of gills; and although no full development of these respirator organs occurs in such animals, they give rise by their various trans formations to the permanent pulmonary and aortic stems and th principal vessels which spring from them.

The form and position of the primitive aortic arches, up to the tim of their transformation into permanent vessels, or their disappearance are nearly the same in reptiles, birds, and mammals; and the mai

differences in the seat and distribution of the large permanent vessels are to be traced to changes in the patency and extent of growth of the several arches. The five pairs of arches do not all co-exist at the same time, for they are developed in succession from before backwards; and by the third day of incubation, or by the corresponding period of the fourth week in the human embryo, when the posterior arches have been formed, already the two anterior arches, beginning with the first one, have become partially obliterated. Each of the first four branchial

Fig. 779.

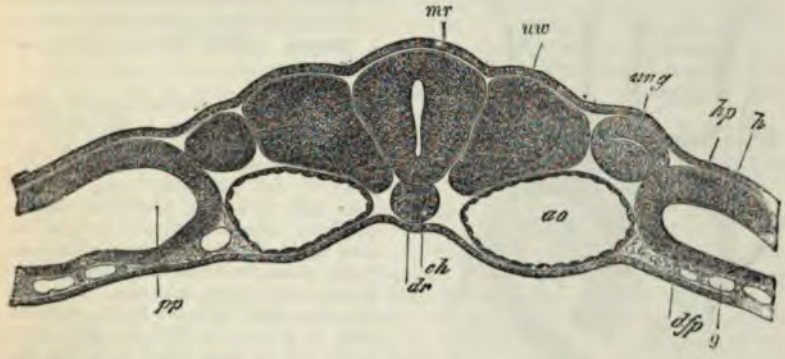


Fig. 779.—Transverse section of an embryo rabbit, of nine days and two hours, in the middle dorsal region. $\frac{15}{1}$. (From Kölliker.)

mr, medullary tube; *uw*, protovertebral mass; *h*, epiblast; *hp*, parietal mesoblast; *dfp*, visceral division of the mesoblast; *pp*, pleuro-peritoneal cavity between them; *ung*, primitive segmental duct; *g*, vessels in the visceral mesoblast; *ch*, notochord; *dr*, intestinal groove of the hypoblast.

arches occupies a place in the substance of the visceral arches, and in front of one of the pharyngeal clefts. The first or anterior is therefore situated in the mandibular arch, and in front of the tympano-Eustachian or hyomandibular cleft; and the fifth arterial arch is placed behind the fourth pharyngeal cleft and in the substance of the neck, in which there is no distinct arch in the higher animals, but which is the seat of a developed branchial bar in some aquatic vertebrates.

The vessels forming the arterial arches are given off on each side in succession from two short canals, into which the primitive arterial bulb divides immediately in front of the place where it joins the neck. These may be named the ventral or anterior aortic roots; and similarly, when they have passed round the wall of the pharynx, the branchial arches unite in succession into a vessel on each side, thus forming the dorsal or posterior aortic roots.

On the third and fourth days in the chick, and from the fourth to the sixth week in the human embryo, there are still three complete pairs of arterial arches passing round the pharynx, and connected both before and behind with the anterior and posterior aortic roots previously mentioned. The transformations of these arches were in part traced by Von Baer and various other observers, but the fuller knowledge of their changes is due to the later researches of Rathke (No. 240, iv); and although some points are still left in doubt, their history may now be given from these observations, which receive interesting illustration from the investigation

of the various examples of congenital malformation, the greater numbe of which are manifestly related to variations in the natural mode o development (see Fig. 780).

From these researches it appears that the permanent vessels owe their forms tion to the persistence of certain of the fœtal arches or parts of them, whil other arches or portions of them become obliterated and disappear. Thus it ascertained that in mammals the main aortic arch, which in the adult passes

Fig. 780.

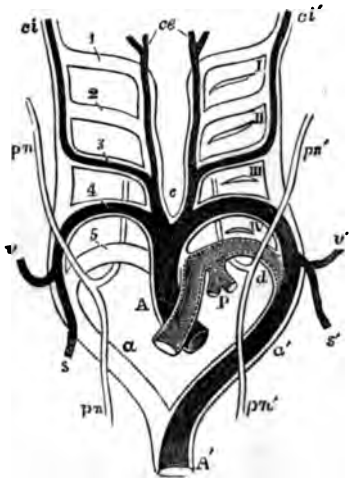


Fig. 780.—DIAGRAM OF THE AORTIC A BRANCHIAL VASCULAR ARCHES OF TH MAMMAL, WITH THEIR TRANSFORMATIO GIVING RISE TO THE PERMANENT ARTERI VESSELS. (After Rathke, slightly a tered.)

A, P, primitive arterial stem or aort bulb, now divided into A, the ascendi part of the aortic arch, and P, the pu monary; *a*, the right; *a'*, the left aort root; A', the descending aorta. On t right side, 1, 2, 3, 4, 5 indicate the f primitive arterial arches; on the l side, I, II, III, IV the four pharyng clefts, which, for the sake of clearness, ha been omitted on the right side. It will observed, that while the fourth and fif pairs of arches rise from the part of t aortic bulb or stem, which is at first u divided, the first, second, and third pai are branches above *c*, of a secondary ste on each side. The permanent system vessels are represented in deep shade, t pulmonary arteries lighter; the parts the primitive arches which have only temporary existence are drawn in outline only. *c*, placed between the permanent co mon carotid arteries; *ce*, the external carotid arteries; *ci*, *ci'*, the right and left intern carotid arteries; *s*, the right subclavian rising from the right aortic root beyond t fifth arch; *v*, the right vertebral from the same opposite the fourth arch; *v'*, *s'*, t left vertebral and subclavian arteries rising together from the left or permanent aort root opposite the fourth arch; P, the pulmonary arteries rising together from the l fifth arch; *d*, the outer or back part of the left fifth arch, forming the ductus arteriosu *pn*, *pn'*, the right and left pneumogastric nerves, descending in front of the aort arches, with their recurrent branches represented diagrammatically as passing behin with a view to illustrate the relations of these nerves respectively to the right subclavi artery (4) and the arch of the aorta and ductus arteriosus (*d*).

the left of the trachea and gullet, is formed by the persistence of the four embryonic arterial arch of the left side, which not only remains patent, a is connected with the aortic stem of the arterial bulb, but by the increa of its width and the thickness of its walls keeps pace in its rate of growth wi that of other parts of the body, so that it soon surpasses all the rest of the arch in its dimensions. In birds, however, the permanent aortic arch is on the rig of the trachea and gullet, being formed by the persistence of the fourth embr onic arch of the right side; while, in all reptiles, as there are two permanen aortic arches, it is by the persistence of both the right and left fourth arch that the two aortas are produced, the right being that which is most directly co nected with the systemic or left ventricle.

The pulmonary arteries of mammals would appear from Rathke's observations t be developed in connection with only one fœtal arterial arch—viz., the fifth o the left side—from the middle part of which they are formed as branches, and th whole fifth arch of the right side after a time undergoes atrophy and obliteratio The first part of the left fifth arch, becoming the common pulmonary artery,

connected with that division of the arterial bulb which is separated as the pulmonary stem; but the remote part of this arch also remains fully patent, and undergoing development equally with the rest of its extent, continues to lead into the *left* root of the aorta as ductus arteriosus Botalli, which serves to convey the blood from the right ventricle of the fœtal heart into the descending aorta, but becomes obliterated at the time of birth.

This duct is therefore in mammals due to a persistent condition of the fifth left branchial arch; but, in birds and reptiles, the process of transformation is somewhat different, for in them the right and left pulmonary arteries (excepting in those serpents in which there is only one lung developed) are formed in connection with the respective right and left fifth branchial arches, and there are thus two ductus arteriosi during fœtal life, the short one of the right side corresponding to that which is *left* or sinistral in mammals, and the longer one of the left side passing round the pharynx into the left aortic root. Both of these arches are obliterated at the time of the exclusion of the bird from the egg; but in some reptiles the ductus arteriosi remain permanently open during life.

The subclavian and vertebral arteries were shown by Rathke to spring from the posterior aortic roots at a place between the junction of the fourth and fifth arches. In mammals, the vessels on the left side are from the first in direct connection with the aortic root at the place which they permanently occupy; but upon the right side, as the fourth arch and the aortic root are obliterated posteriorly, the passage for blood from the aortic stem into the subclavian trunk is formed by the persistence of the forepart of the fourth right arch as far as the place where it meets the origin of the subclavian and vertebral arteries.

The common carotid trunks, occupying the region which afterwards becomes the neck, but which is at first absent or extremely short, are formed by the anterior divisions of the aortic roots; while the external carotid artery is due to the persistence of a channel in the continuation of each anterior aortic root, and the internal carotid artery arises from the persistence of the crossing third arch and the upper part of the posterior aortic root.

Thus it falls out that, in man and a certain number of mammals, an innominate artery is formed on the right side by the union of the first part of the fourth right aortic arch leading into the right subclavian with the right anterior aortic root which forms the common carotid; while, on the left side, the carotid and subclavian vessels rise separately from the permanent aortic arch in consequence of the distance between them in the original fœtal condition.

It does not come within the scope of this work to describe the further steps of development of these vessels, nor to enter into an explanation of the manner in which abnormal position of the arch of the aorta and its branches, or of the pulmonary arteries, may be supposed to arise. For further information on this subject the reader is referred to the short account of the varieties given in the description of the blood-vessels in the first volume of this work, as well as to the third volume of Henle's Handbuch, and to the special works of Tiedemann and Richard Quain on the arteries.

THE GREAT VEINS.

In the early embryo, before the development of the allantois, a right and a left vitelline (or omphalo-mesenteric) vein bring back the blood from the walls of the umbilical vesicle, and unite to form a short trunk, the meatus venosus, which is continued into the auricular extremity of the rudimentary heart.

In the first commencement of the allantoid circulation, or in the fourth week of fœtal life, two umbilical veins are seen coming from the placenta, and uniting to form a short trunk, which opens into the common vitelline vein. Very soon the right vitelline vein and right umbilical vein disappear. In connection with the common trunk of these veins, proceeding to the liver, two sets of vessels make their appearance in the early stage of its growth. Those furthest from the heart, named *venæ hepaticæ advehentes*, become the right and left divisions of the portal vein; the others are the hepatic veins, *venæ hepaticæ revehentes*. The portion of vessel intervening between those two sets of veins

forms the *ductus venosus*, and the part above the hepatic vein, being subsequently joined by the ascending vena cava, forms the upper extremity of that vein. Into the remaining or left vitelline vein there open the mesenteric and splenic veins. The part above the latter forms the trunk of the portal vein; and the portion

Fig. 781.

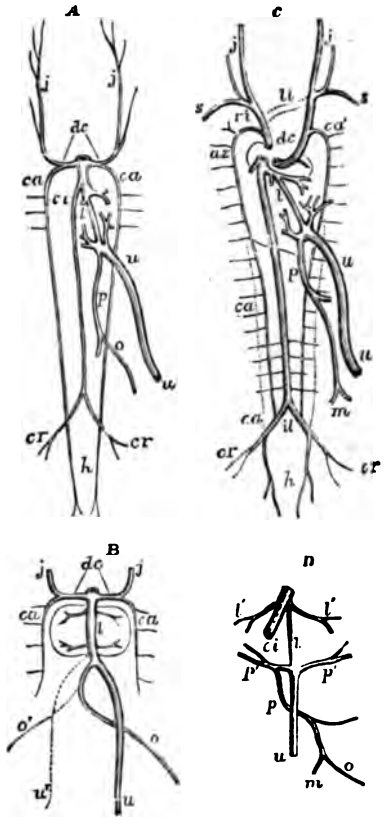


Fig. 781.—Diagrams illustrating the development of the great veins. (After Kölliker.)

A, plan of the principal veins of the fœtus of about four weeks, or soon after the first formation of the vessels of the liver and the vena cava inferior.

B, veins of the liver at a somewhat earlier period.

C, principal veins of the fœtus after the establishment of the placental circulation.

D, veins of the liver at the same period.

dc, the right and left ducts of Cuvier; *ca*, the right and left cardinal veins; *j*, *j*, the jugular veins; *s*, the subclavian veins; *az*, the azygos vein; *u*, the umbilical or left umbilical vein; *u'*, in B, the temporary right umbilical vein; *o*, the vitelline vein; *o'*, the right; *m*, the mesenteric veins; *p*, the portal vein; *P'*, *P'*, the venæ advehentes; *l*, the ductus venosus; *l'*, *l'*, the hepatic veins; *ci*, vena cava inferior; *il*, the division of the vena cava inferior into common iliac veins; *cr*, the external iliac or crural veins; *h*, the hypogastric or internal iliac veins, in the line of continuation of the primitive cardinal veins.

In C, *li*, in dotted lines, the transverse branch of communication between the jugular veins which forms the left brachio-cephalic vein; *ri*, the right brachio-cephalic vein; *ca'*, the remains of the left cardinal vein by which the superior intercostal veins fall into the left brachio-cephalic vein; above *P*, the obliquely crossing vein by which the hemi-azygos joins the azygos vein.

of vessel between the union of this with the umbilical vein and the origin of the venæ hepaticæ advehentes is so altered that the portal trunk opens into the commencement of the right vena advehens.

At the time of the commencement of the placental circulation, two short transverse venous trunks, the *ducts of Cuvier*, open, one on each side, into the auricle of the heart. Each is formed by the union of a superior and an inferior vein, named respectively the *primitive jugular* and the *cardinal*.

The *primitive jugular* vein receives the blood from the cranial cavity by channels in front of the ear, which are subsequently obliterated: in the greater part of its extent it becomes the internal jugular vein; and near its lower end it receives small branches, which grow to be the external jugular and subclavian veins. The *cardinal veins* are the primitive vessels which return the blood from the Wolffian bodies, the vertebral column, and the parietes of the trunk. The inferior vena cava is a vessel of later development, which opens into the trunk of the umbilical and vitelline veins, above the venæ hepaticæ revehentes. The iliac veins, which unite to form the inferior vena cava, communi-

cate with the cardinal veins. The inferior extremities of the cardinal veins are persistent as the internal iliac veins. Above the iliac veins the cardinal veins are obliterated in a considerable part of their course; their upper portions then become continuous with two new vessels, the *posterior vertebral veins* of Rathke, which receive the lumbar and intercostal twigs.

As development proceeds, the direction of the ducts of Cuvier is altered by the

Fig. 782.

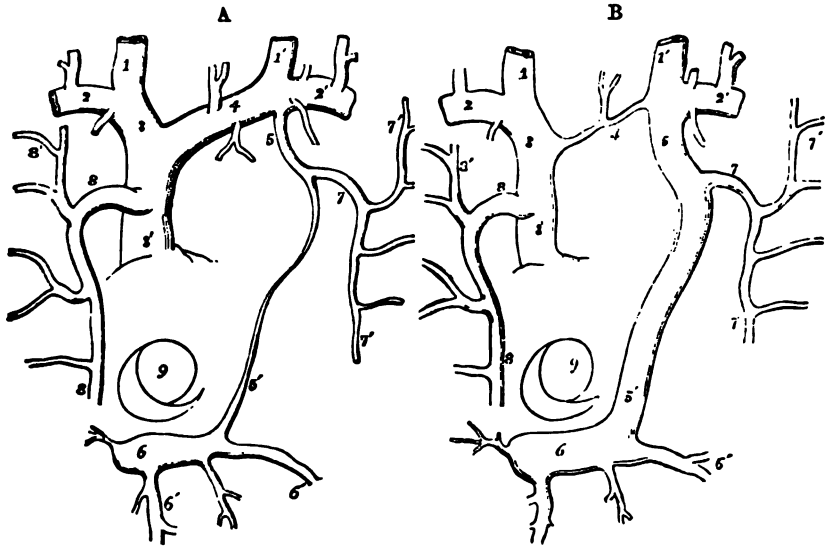


Fig. 782.—A and B.—DIAGRAMMATIC OUTLINES OF THE VESTIGE OF THE LEFT SUPERIOR CAVA AND OF A CASE OF ITS PERSISTENCE. (Sketched after Marshall.) ½.

A, brachio-cephalic veins with the superior intercostal, azygos, and principal cardiac veins. (In this and in B the veins are supposed to be seen from before.)

B, the same in a case of persistence of the left superior cava, showing its communication with the sinus of the coronary vein. The views are supposed to be from before, the parts of the heart being removed or seen through.

1, 1′, the internal jugular veins; 2, 2′, subclavian veins; 3, right innominate; 3′, right or regular superior cava; 4, in A, the left innominate; in B, the transverse or communicating vein between the right and left superior venæ cavæ; 5, in A, the opening of the superior intercostal vein into the innominate; 5′, vestige of the left superior cava or duct of Cuvier; 5, 5′, in B, the left vena cava superior abnormally persistent, along with a contracted condition of 4, the communicating vein; 6, the sinus of the coronary vein; 6′, branches of the coronary veins; 7, the superior intercostal trunk of the left side, or left cardinal vein; 8, the principal azygos or right cardinal vein; 7′, 8′, some of the upper intercostal veins; 9, the opening of the inferior vena cava, with the Eustachian valve.

descent of the heart from the cervical into the thoracic region, and becomes the same as that of the primitive jugular veins. A communicating branch makes its appearance, directed transversely from the junction of the left subclavian and jugular veins, obliquely across the middle line to the right jugular; and further down in the dorsal region between the posterior vertebral veins a communicating branch passes obliquely across the middle line from right to left. The communicating branch between the primitive jugular veins is converted into the left brachio-cephalic or innominate vein. The portion of vessel between the right subclavian vein and the termination of the communicating branch becomes the right brachio-cephalic vein. The portion of the primitive jugular vein below the communicating vein, together with the right duct of Cuvier, forms

the vena cava superior, while the cardinal vein opening into it is the extremity of the great vena azygos. On the left side, the portion of the primitive jugular vein placed below the communicating branch, and the cardinal and posterior vertebral veins, together with the cross branch between the two posterior vertebral veins, are converted into the left superior intercostal and left superior and inferior azygos veins. The variability in the adult arrangement of these vessels depends on the

Fig. 783.

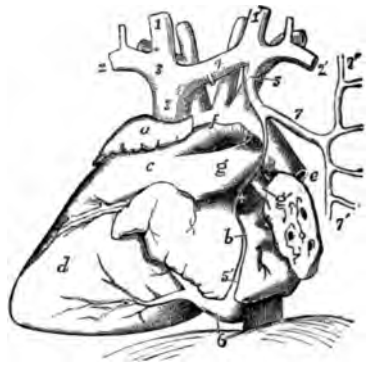


Fig. 783.—VIEW OF THE FŒTAL HEART AND GREAT VESSELS, FROM THE LEFT SIDE, TO SHOW THE VESTIGE OF THE LEFT SUPERIOR CAVA VEIN IN SITU. (This figure is planned after one of Marshall's, and slightly altered according to an original dissection.)

a, right auricle; *b*, left auricle and pulmonary veins; *c*, the conus arteriosus of the right ventricle; *d*, the left ventricle; *e*, descending aorta; +, vestigial fold of the pericardium; *f*, arch of the aorta, with a part of the pericardium remaining superiorly; *g*, main pulmonary artery and ductus arteriosus; *g'*, left pulmonary artery; 1, 1', right and left internal jugular veins; 2, 2', subclavian veins; 3, 3', right innominate and superior vena cava; 4, left innominate or communicating vein; 5, 5', remains of the left superior cava and duct of Cuvier, passing at + in the vestigial fold of the pericardium, joining the coronary sinus, 6, below, and receiving above the superior intercostal vein, 7; 7', 7', the upper and lower intercostal vein, joining into one.

different extent to which the originally continuous vessels are developed or atrophied at one point or another. The left duct of Cuvier is obliterated, except at its lower end, which always remains pervious as the coronary sinus. But even in the adult, traces of this vessel can always be recognised in the form of a fibrous band, or sometimes a narrow vein, which descends obliquely over the left auricle; and in front of the root of the left lung there remains a small fold of the serous membrane of the pericardium, the *vestigial fold*, so named by Marshall, to whom is due the first full elucidation of the nature and relations of the left primitive vena cava superior (No. 253).

The left duct of Cuvier has been observed persistent as a small vessel in the adult. Less frequently a right and a left innominate vein open separately into the right auricle, an arrangement which is also met with in birds and in certain mammals, and which results from the vessels of the left side being developed similarly to those of the right, while the cross branch remains small or absent (Quain, No. 243).

A case is recorded by Gruber (No. 254) in which the left vena azygos opened into the coronary sinus, and was met by a small vein descending from the union of the subclavian and jugular. Here, then, the jugular veins had been developed in the usual manner, while the left vena azygos continued to pour its blood into the duct of Cuvier.

III. PECULIARITIES OF THE FŒTAL ORGANS OF CIRCULATION.

It may be useful here to recapitulate shortly the peculiarities of structure existing in the advanced stage of the formation of the fœtal organs of circulation, with reference to their influence in determining the course of the blood during intra-uterine life, and the changes which occur in them upon the establishment of pulmonary respiration at birth.

1. The **foramen ovale** retains the form of a free oval opening in the septum auricularum up to the fourth month, but in the course of that month and the next the growth of the valvular plate or curtain, which fills up the floor of the fossa

ovalis, becomes complete, so that in the last three and a half months the blood can only pass from the right into the left auricle, but not in a contrary direction.

2. The Eustachian Valve constitutes a crescentic fold of the lining structure of the heart, which is so situated as to direct the blood entering the auricle by the inferior cava towards the opening of the foramen ovale.

Fig. 784.

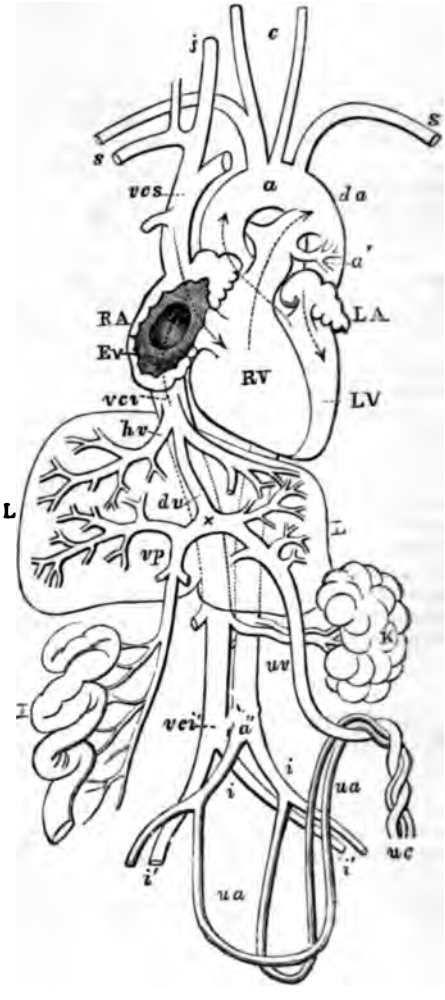


Fig. 784.—DIAGRAMMATIC OUTLINE OF THE ORGANS OF CIRCULATION IN THE FŒTUS OF SIX MONTHS. (A. T.)

RA, right auricle of the heart; **RV**, right ventricle; LA, left auricle; Ev, eustachian valve; **LV**, left ventricle; L, liver; K, left kidney; I, portion of small intestine; *a*, arch of the aorta; *a'*, its dorsal part; *a''*, lower end; *vcs*, superior vena cava; *vci*, inferior vena where it joins the right auricle; *vci'*, its lower end; *s*, subclavian vessels; *j*, right jugular vein; *c*, common carotid arteries; four curved dotted arrow lines are carried through the aortic and pulmonary opening, and the auriculo-ventricular orifices; *da*, opposite to the one passing through the pulmonary artery, marks the place of the ductus arteriosus; a similar arrow line is shown passing from the vena cava inferior through the fossa ovalis of the right auricle, and the foramen ovale into the left auricle; *hv*, the hepatic veins; *vp*, vena portæ; *x* to *vci*, the ductus venosus; *uv*, the umbilical vein; *ua*, umbilical arteries; *uc*, umbilical cord cut short; *i i'*, iliac vessels.

3. The ductus arteriosus establishes a communication between the main pulmonary artery and the aorta, by which the blood from the right ventricle is carried mainly into the dorsal aorta.

4. Umbilical Vessels.—The two large hypogastric or *umbilical arteries*, prolonged from the iliac arteries, passing out of the body of the fœtus, proceed along the umbilical cord, to be distributed in the fœtal portion of the placenta. From the placenta the blood is returned by the umbilical vein, which, after entering the abdomen, communicates by one branch with the portal vein of the liver, and is continued by another, named *ductus venosus*, into one of the hepatic veins, through which it joins the main stem of the vena cava inferior.

Course of the Blood in the Fœtus.—The right auricle of the fœtal heart receives blood from the two venæ cavæ and the coronary vein. The blood brought by the superior cava is simply the venous blood returned from the head

and upper half of the body; whilst the inferior cava, which is considerably larger than the superior, conveys not only the blood from the lower half of the body, but also that which is returned from the placenta and from the liver. This latter stream of blood reaches the vena cava inferior, partly by a direct passage—the *ductus venosus*—and partly by the hepatic veins, which bring to the vena cava inferior all the blood circulating through the liver, whether derived from the supply of placental blood entering that organ by the umbilical vein, or proceeding from the vena portæ or hepatic artery.

The blood of the superior vena cava, passing from the right auricle into the right ventricle, is thence propelled into the trunk of the pulmonary artery. A small part of it is distributed through the branches of that vessel to the lungs, and returns by the pulmonary veins to the left auricle; but, as these vessels remain comparatively undilated up to the time of birth, by far the larger part passes through the ductus arteriosus into the dorsal aorta, and is thence distributed in part to the lower half of the body and the viscera, and in part is conveyed along the umbilical arteries to the placenta. From these several organs it is returned by the vena cava inferior, the venæ portæ, and the umbilical vein; and, as already noticed, reaches the right auricle through the trunk of the inferior cava.

Of the blood entering the heart by the inferior vena cava, only a small part is mingled with that of the superior cava, so as to pass into the right ventricle; by far the larger portion, directed by the Eustachian valve through the foramen ovale, flows into the left auricle, and thence, together with the small quantity of blood returned from the lungs by the pulmonary veins, passes into the left ventricle, from whence it is sent into the arch of the aorta, to be distributed almost entirely to the head and upper limbs.

Sabatier was the first to call attention particularly to the action of the Eustachian valve in separating the currents of blood entering the right auricle by the superior and inferior venæ cavæ (No. 236). This separation, as well as that occurring between the currents passing through the aortic arch and the ductus arteriosus into the descending aorta, was illustrated experimentally by John Reid (No. 241). A striking confirmation of the extent to which the last mentioned division of the two currents of the fœtal blood may take place, without disturbance of the circulation up to the time of birth, is afforded by the examples of malformation in which a complete obliteration has existed in the aortic trunk immediately before the place of the union of the ductus arteriosus with the posterior part of the aortic arch.

CHANGES IN THE CIRCULATION AT BIRTH.

The changes which occur in the organs of circulation and respiration at birth, and which lead to the establishment of their permanent condition, are more immediately determined by the inflation of the lungs with air in the first respiration, the accompanying rapid dilatation of the pulmonary blood-vessels with a greater quantity of blood, and the interruption to the passage of blood through the placental circulation. These changes are speedily followed by shrinking and obliteration of the ductus arteriosus, in the space between the division of the right and left pulmonary arteries and its junction with the aorta, and of the umbilical arteries from the hypogastric trunk to the place of their issue from the body by the umbilical cord; by the cessation of the passage of blood through the foramen ovale, and somewhat later by the closure of that foramen, and by the obliteration of the umbilical vein as far as its entrance into the liver, and of the ductus venosus within that organ.

The process of obliteration of the arteries appears to depend at first mainly on the contraction of their coats, but this is very soon followed by a considerable thickening of their substance, reducing rapidly their internal passage to a narrow tube, and leading in a short time to final closure, even although the vessel may not present externally any considerable diminution of its diameter. It commences at birth, and is perceptible after a few respirations have occurred. It makes rapid progress in the first and second days, and by the third or fourth day the passage through the umbilical arteries is usually completely interrupted.

The ductus arteriosus is rarely found open after the eighth or tenth day, and by three weeks it has in almost all instances become completely impervious.

The process of closure in the veins is slower, there not being the same thickening or contraction of their coats; but they remain empty of blood and collapsed, and by the sixth or seventh day are generally closed.

Although blood ceases at once to pass through the foramen ovale from the moment of birth, or as soon as the left auricle becomes filled with the blood returning from the lungs, and the pressure within the two auricles is equalised, yet the actual closure of the foramen is more tardy than any of the other changes now referred to. It is gradually effected by the union of the forepart of the valvular fold forming the floor of the fossa ovalis with the margin of the annulus on the left side; but the crescentic margin is generally perceptible in the left auricle as a free border beyond the place of union, and not unfrequently the union remains incomplete, so that a probe may be passed through the reduced aperture. In many cases a wider aperture remains for more or less of the first year of infancy, and in certain instances there is such a failure of the union of the valve as to allow of the continued passage of venous blood, especially when the circulation is disturbed by over-exertion, from the right to the left auricle, as occurs in the malformation attending the morbus cœruleus.

LYMPHATIC SYSTEM.

Closely connected with the blood-vascular system, and also arising from the mesoblast, are the less conspicuous and sometimes rather indefinite components of the lymphatic system, consisting of the lymphatic vessels, glands, and the lymph spaces, the histological development of which has been referred to in the first part of this volume (p. 208).

Like the bloodvessels, the lymphatic vessels are intimately associated with the connective tissue, and they take their origin in a somewhat similar manner in spaces which are formed in the primitive blastema. It is also an interesting fact that these vessels are in frequent communication with the intermesoblastic space or pleuro-peritoneal cavity.

All the lymphatic vessels are at first similar to capillary bloodvessels, being lined only by flat epithelium; and many of them, though of some size, do not pass beyond this stage, while others acquire fibrous, contractile, and adventitious coats in a manner exactly the same as do the arteries or veins.

The lymphatic glands consist at first of networks of lymphatic vessels and spaces having numerous lymph cells produced within them; but later they have added to them connective tissue elements and bloodvessels in considerable quantity.

The Spleen.—There is perhaps none of the organs which have been ranked as vascular glands which so well deserves the name as the spleen, for it appears to be closely associated with both the lymphatic and the blood-vascular systems. It is not formed at a very early stage of development, but begins to appear in the human embryo in the latter half of the second month. It is developed in the substance of the mesogastrium, and is at first in close connection with the pancreas, but without any hypoblastic evolution, and proceeding entirely from mesoblast, apparently from the same mass as that in which the pancreas takes its origin (W. Müller, No. 256). Its progress is not rapid: it acquires vessels and trabecular fibres in the third month, and there is a large increase of the cells of the pulp; but the Malpighian corpuscles are only formed later, and are not distinctly seen till near the end of fœtal life. For the development of the Thyroid and Thymus Glands see p. 889.

IV. DEVELOPMENT OF THE ALIMENTARY CANAL AND ASSOCIATED ORGANS.

The parts of the body of which the development has been previously described all take their origin from either or both of the upper and middle layers of the blastoderm. Those which are now to be considered proceed, in the first instance, from the inflections and growth of the hypoblast or lower layer, with which, however, there are combined, in almost all of the organs, elements which are derived from the visceral layer of the mesoblast. These organs consist of the alimentary canal, with its integral and accessory glands, such as the liver and pancreas, the respiratory organs, the larynx, trachea, and lungs, the serous coverings of pleuræ and peritoneum, &c.

Primary Development.—Mesenteron.—The principal part of the alimentary canal is formed at first by a simple inflection of the hypoblast, and its wall then consists of no more than the epithelial cells derived from that layer of the blastoderm. In the most of its extent, however, this epithelial wall has acquired considerable thickness as compared with the part of the hypoblast external to the body of the embryo.

The primary digestive cavity of birds and mammals, as it extends from one end of the embryo to the other below the vertebral axis, and

Fig. 785.

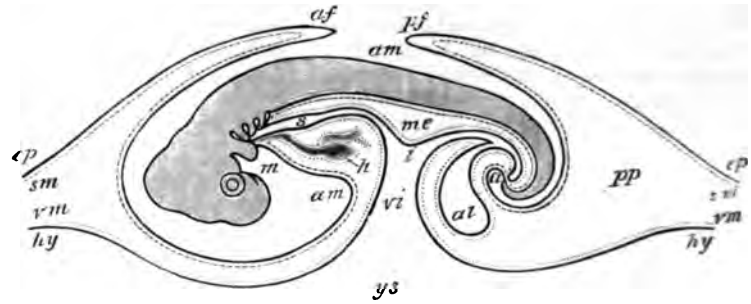


Fig. 785.—Enlarged diagrammatic outline of a longitudinal vertical section of the chick and neighbouring parts of the blastoderm on the fourth day. (A. T.)

ep, epiblast, and *sm*, somatic mesoblast, together forming the *somatic plate*; *hy*, hypoblast, and *vm*, visceral mesoblast, together forming the *visceral plate*; *af*, cephalic fold; *pf*, caudal fold of the amnion; *am*, cavity of the true amnion; *ys*, yolk-sack, leading by the vitello-intestinal aperture to *i*, the intestine; *s*, the stomach and pharynx; *a*, the future anus still closed; *m*, the buccal cavity or mouth formed in epiblast and still closed from the pharynx at the fauces, which are not shown; *me*, the mesentery; *al*, the allantoid vesicle communicating by its pedicle with the hinder intestine; *pp*, the space between the outer and inner folds of the amnion, which is an extension of the body cavity or pleuro-peritoneal space within the embryo between the somatic and visceral mesoblasts. The shaded part of the figure represents the head and trunk of the embryo in which the eye and the jaws with the branchial bars and clefts are indicated. The epiblast and hypoblast are drawn with entire lines, the somatic mesoblast with an interrupted and the visceral mesoblast with a dotted line.

not including the buccal and anal portions derived from epiblastic involution, presents at first a manifest division into three parts. One of these, occupying the part of the embryo which is enclosed by the cephalic

fold, and which may be named the *foregut*, comprises the rudiments of the pharynx and gullet, the stomach and duodenum. The posterior division, which is comparatively short, occupies the caudal fold of the embryo, and corresponds mainly to the parts in the neighbourhood of the future anus, with a prolongation of the gut, which may be called post-

Fig. 786.—The same embryo as in fig. 667 removed from the membranes, more highly magnified and seen from below. (From Kölliker after Coste.)

a, allantois already forming an umbilical pedicle; *u*, urachus or stalk; *i*, hinder gut; *v*, amnion; *o*, yolk-sac; *g*, primitive aortas lying under the vertebral column, separated by the white line; *x*, wide opening of the intestine into the yolk-sac; *k*, place where the umbilical and omphalo-mesenteric veins meet and pass into the heart; *p*, pericardial cavity; *c*, heart; *h*, aorta; *t*, frontal process.

Fig. 786.

anal or sub-caudal. Both of these parts have from the first a tubular form, and are closed respectively by the inflection of the whole blastodermic layers at the anterior and posterior extremities of the body. The middle division, or that in which the greater part of the small and large intestines will afterwards be formed, has primarily the form of a long and wide groove, lying close below the vertebral bodies, and leading at its opposite ends into the cephalic and caudal portions of the gut; it is freely open throughout on its ventral aspect into the cavity of the yolk-sac, with the blastodermic walls of which, as formerly described, the constituents of the intestinal walls are directly continuous.

Foregut.—As development proceeds in the forepart of the alimentary canal, a change in its form manifests itself, by which one part, becoming dilated, forms the commencement of the stomach, while the others remain of smaller diameter as gullet and duodenum; and in connection with different parts of these the rudiments of the lungs, liver, and pancreas are first formed.

When the tubular parts of the gut have attained to some length, a change of position gradually accompanies their further development. While the œsophageal part remains comparatively straight, the dilated portion of the tube which forms the stomach turns over on its right side, so that the border which is connected to the vertebral column by the mesenteric fold (or true mesogastrium) comes to be turned to the left—the position of the tube being still vertical, like the stomach of some animals. By degrees it becomes more dilated, chiefly on what is now the left border but subsequently becomes the great curvature, and assumes more of the oblique position of the adult, carrying with it the mesogastrium, from which the great omentum is afterwards produced. A slight indication of the pylorus is seen at the third month. Upon the surface of the part of the canal which immediately succeeds the stomach, and which forms the duodenum, the rudiments of the liver, pancreas,

and spleen are simultaneously deposited, in the manner stated in the description of the development of these organs.

Midgut.—Previously to the occurrence of the changes in the foregut mentioned above, the middle open part shortens, more and more of it being converted into the tubular intestine, and at last, as before

Fig. 787.

Fig. 787.—HUMAN EMBRYO OF THIRTY-FIVE DAYS SEEN FROM BEFORE. (From Kölliker after Coste.)

3, left external nasal process; 4, superior maxillary process; 5, lower maxillary process; z, tongue; b, aortic bulb; b′, third aortic arch or carotid stem; b″, fourth or main aortic arch; b‴, fifth arch or ductus Botalli; c, the superior cava and right azygos vein; c′, the common venous sinus of the heart; c″, the common stem of the left vena cava and left azygos; o′, left auricle of the heart; v, right; v′, left ventricle; a e, lungs; e, stomach; j, left omphalo-mesenteric vein; s, continuation of the same behind the pylorus, which becomes afterwards the vena portæ; x, vitello-intestinal duct; a, right omphalo-mesenteric artery; m, Wolffian body; i, rectum; n, umbilical artery; u, umbilical vein; 8, tail; 9, anterior; 9′, posterior limb. The liver has been removed.

explained, there remains only the narrow opening by which the gradually lengthening ductus vitello-intestinalis leads into the umbilical vesicle. The middle part of the intestinal canal has, when first produced, more or less the form of a straight tube lying close to the vertebral column; but, as soon as it increases in length, it is thrown into the shape of a loop bent downwards to the umbilicus—a change which is preceded and accompanied by the formation of the mesentery. The latter structure is undoubtedly entirely due to a proliferation and median union of mesoblastic elements, which, extending themselves between the mesoblast surrounding the notochord and the elongating gut, become developed into the vascular and other parts of the mesentery, as was long ago shown by Von Baer. The mesentery thus forms a mesial partition extending between the gut and the dorsal wall of the embryo, at first quite simple, but afterwards elongating, and becoming more complicated in proportion to the development of the intestinal tube. The mesoblast also, by its visceral division, furnishes the contractile, vascular, and connective tissue elements of the intestinal walls. The extent to which the glandular elements of the alimentary canal are supplied by the hypoblast, to which their origin was entirely attributed by Remak, or furnished rather by mesoblast from the protovertebral mass, as held by Schenk, is not yet fully determined.

The place of transition from the small to the large intestine, which

is soon indicated by the protrusion of the cæcum, is at a point just behind the apex or middle of the simple loop already mentioned as existing after the first elongation of the tubular gut. As the *small* intestine grows, the part behind the duodenum forms coils, some of which at first lie in a dilatation of the commencing umbilical cord (see fig. 789), but retire again into the abdomen about the twelfth week; afterwards, as it continues to elongate, its convolutions become more and more numerous.

The *large* intestine is at first less in calibre than the small. In the

Fig. 788.

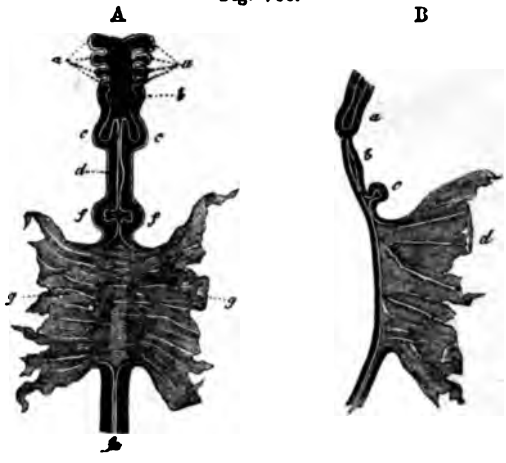


Fig. 788.—Early form of the alimentary canal (from Kölliker after Bischoff).

In A a front view, and in B an antero-posterior section are represented.

In A, *a*, four pharyngeal or visceral plates; *b*, the pharynx; *c*, *c*, the commencing lungs; *d*, the stomach; *f*, *f*, the diverticula connected with the formation of the liver; *g*, the yolk-sac into which the middle intestinal groove opens; *h*, the posterior part of the intestine. In B, *a*, the commencing lungs; *b*, the stomach; *c*, the liver; *d*, the yolk-sac.

early embryo there is at first no cæcum; but this part of the bowel gradually grows out from the rest, forming at first a tube of uniform calibre, without any appearance of the vermiform appendix: subsequently the terminal part of the diverticulum ceases to grow in the same proportion as the rest, and narrows into the appendix, whilst the proximal part attains its full development. The cæcum first appears as a protrusion a little below the apex of the bend in the primitive intestinal canal, and, together with the commencing colon, and the coils of small intestine, is lodged for a time in the wide part of the umbilical cord already mentioned as being next the body of the embryo. The ileo-cæcal valve appears at the commencement of the third month. When the coils of intestine and the cæcum have retired from the umbilicus into the abdomen, the colon is at first entirely to the left of the convolutions of the small intestines, but subsequently the first part of the large intestine, together with the mesocolon, crosses over the upper part of the small intestine, at the junction of the duodenum and jejunum. The cæcum and transverse colon are then found in the middle of the abdomen just below the liver; some time later the cæcum descends to the right iliac fossa, and the parts are nearly in the same position as in the adult.

At first, villous processes or folds of various lengths are formed throughout the whole canal. After a time these disappear in the stomach and large intestine, but remain persistent in the intermediate portions of the tube. According to Meckel, the villous processes are formed from

larger folds, which become serrated at the edge, and are thus divided into separate villi.

Hindgut.—The formation of the hinder part of the gut is complicated with the development of the allantois, which arises as a projection or out-growth of the mesoblast and hypoblast from the lower wall of its terminal portion, and which is therefore in connection internally with the hypoblastic lining of the cloaca.

Fig. 789.

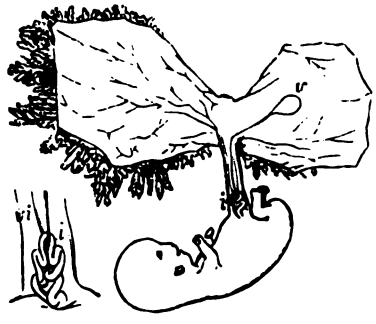


Fig. 789. — SKETCH OF THE HUMAN EMBRYO OF THE TENTH WEEK, SHOWING THE COIL OF INTESTINE IN THE UMBILICAL CORD. (A. T.)

The amnion and villous chorion have been opened and the embryo drawn aside from them; *v*, the umbilical vesicle or yolk-sac placed between the amnion and chorion, and connected with the coil of intestine, *i*, by a small or almost linear tube; the figure at the side represents the first part of the umbilical cord magnified; *i*, coil of intestine; *vi*, vitello-intestinal duct, alongside of which are seen omphalo-mesenteric blood-vessels.

Mesentery, Peritoneum and Diaphragm.—In the region of the pharynx and gullet the undivided mesoblast furnishes the outer coat of the alimentary canal, but in the stomach, and all the remainder of the gut, except at the anus, the separation of the two layers of mesoblast has taken place, and the visceral mesoblast furnishes the outer wall, together with the serous covering. In the thorax the right and left cavities remain distinct as the two pleuræ, while a portion still further forward is separated for the formation of the pericardium, and thus the gullet, as well as the lungs, is brought into relation with the pleuræ, and receives partial covering from them. The formation of the diaphragm, which does not at first exist, and which constitutes in mammals a partition between the thorax and abdomen, leads to the ultimate separation of the peritoneum from the pleuræ. Kölliker conjectures that the diaphragm may be formed by the advance of two halves from the dorsal and lateral regions, but the mode of origin of this partition is not yet sufficiently known (see Cadiat., No. 271), (His. No. 132, i. and ii.). Some examples of diaphragmatic hernia may be considered as arising from the persistence of the original connection between the two cavities. In the abdomen, also, the right and left peritoneal cavities are at first distinct, but when the intestine assumes a tubular form, these cavities are thrown into one across the middle plane of the body.

The peritoneum, like the rest of the lining of the body-cavity, is developed locally by superficial delamination from the mesoblast, and not from any special layer of formative tissue. The stomach is originally placed longitudinally in the abdomen, that part of it which afterwards forms the great curvature being situated dorsally and being attached by the simple mesogastrium. Very soon, a change of place occurs by which the pyloric part of the stomach and the duodenum pass to the right side, the left side of the primitive stomach thus coming to look ventrally and the right side dorsally. About the same time the mesogastrium is rapidly expanded and doubled upon itself so as to enclose a cavity,

while a fold of peritoneum connected with the liver, and arising from the ventral border of the stomach which has now become the lesser curvature, contracts round the entrance to the great omental cavity (behind the stomach and within the omentum) so as to form the gastrohepatic omentum and the foramen of Winslow (as first shown by Joh. Müller in 1830). The dorsal fold of the great omentum has not at first any connection with the transverse colon or its mesocolon, and there can be no doubt that it is only at a later period that it comes to be so closely united with them as to have given rise to the view, quite inconsistent with the history of its development now stated, that the transverse colon is enclosed between the two posterior layers of the omentum.

The occurrence of umbilical hernia in its various degrees may be referred to the persistence of one or other of the fœtal conditions in which a greater or less portion of the intestinal canal is contained in the

Fig. 790.

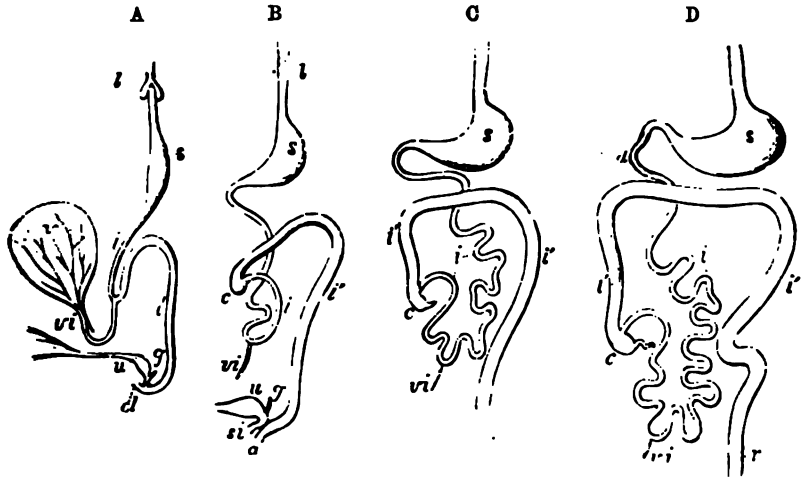


Fig. 790.—Outline of the form and position of the alimentary canal in successive stages of its development.

A, alimentary canal, &c., in an embryo of five weeks; B, at eight weeks; C, at ten weeks; D, at twelve weeks; *l*, the primitive lungs connected with the pharynx; *s*, the stomach; *d*, duodenum; *i*, the small intestine; *i'*, the large; *c*, the cæcum and vermiform appendage; *r*, the rectum; *cl*, in A, the cloaca; *a*, in B, the anus distinct from *si*, the sinus uro-genitalis; *v*, the yolk-sac: *vi*, the vitello-intestinal duct; *u*, the urinary bladder and urachus leading to the allantois; *y*, the genital ducts. In B, and C, the thickness of the colon is erroneously represented as greater than that of the ileum, and in C and D the cæcum as too far down and to the right.

umbilical cord; and it has been shown that the most common form of abnormal diverticula from the small intestine is connected with the original opening of the ductus vitello-intestinalis into the ileum.

Stomodæum.—The mouth, as elsewhere explained, is at first no part of the primitive alimentary canal, but is formed by involution of parts of the face, and receives, therefore, its lining membrane from epiblast. In this stage it has received the name of *stomodæum*. It is at first quite separated from the pharynx, which is the foremost part of the primitive alimentary canal, by the reflection of the layers of the blastoderm; and the com-

munication which is later established between the mouth and pharynx at the posterior arch of the fauces is due to a solution of continuity in these layers, which occurs in the chick at the end of the fourth day of incubation, and has been observed at a corresponding period of development in several mammals. The aperture has at first the form of a vertical slit, which widens later as it becomes the opening from the pharynx into the common cavity of the nose and mouth. The diverticulum of the pituitary gland occupies the place which becomes the top of the permanent pharynx, but is formed in connection with the epiblastic or buccal, and not the hypoblastic or pharyngeal division of the alimentary passage (see fig. 705, A and B, *f*).

Proctodæum.—To the anal invagination of the epiblast, in so far as it is separate from the primitive hypoblastic part of the hind gut, the name of *proctodæum* has been given.

In mammals there is very little anal invagination of the epiblast; in

Fig. 791.

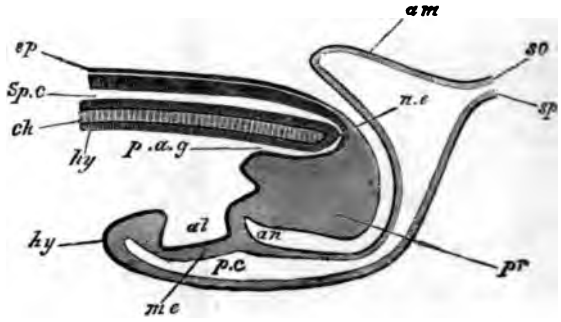


Fig. 791.—DIAGRAMMATIC LONGITUDINAL SECTION OF THE HINDER PART OF AN EMBRYO CHICK AT THE TIME OF THE FORMATION OF THE ALLANTOIS (from Balfour).

ep, epiblast; *Sp.c*, spinal canal; *ch*, notochord; *n.e*, neurenteric canal; *hy*, hypoblast; *p.a.g*, postanal gut; *pr*, remains of primitive streak folded in on the ventral side; *al*, allantois; *me*, mesoblast; *an*, place of future anus; *pc*, perivisceral cavity; *am*, amnion; *so*, body-wall; *sp*, visceral wall.

birds it is more extended from the development of the *bursa Fabricii* in connection with it, and the opening of the gut into the anus occurs at a comparatively late period, or not till the fifteenth day (Kölliker). In the rabbit the opening takes place on the eleventh or twelfth day. The subcaudal or postanal portion of the gut shrinks and disappears even before the opening takes place. The terminal portion of the gut remains behind the allantoid pedicle, and the whole of the tissues which close it thinning rapidly away, perforation takes place so as to form the primitive anal, or rather the cloacal opening. The separation of the permanent anus from the urogenital orifice, which occurs in all mammals excepting the monotremata, is the result of a later process of development, to be referred to in the next section. (Gasser, No. 272.)

THE LIVER AND PANCREAS.

The Liver.—The liver is one of the earliest formed abdominal organs. It consists at first, according to most observers, of a bud mass of cells in connection with the lower surface of the duodenal portion

of the alimentary canal. A hollow cavity soon appears within the mass, which is the commencement of the main excretory duct (ductus choledochus communis). This cavity is lined by hypoblastic epithelium; and, according to the commonly received view, is produced as a diverticulum of the hypoblast of the intestine. Through the liver mass, but at first unconnected with its substance, there passes the main stem of the veins from the umbilical vesicle and allantois (umbilical vein or meatus venosus).

In the rudimentary mass composing the liver there are soon observed a number of solid cylinders of formative cells which branch out from the hypoblast into the mesoblast, and with this peculiarity belonging to the structure of the liver as compared with other glands, that, as these unite together by their ends and also laterally, they come at last to form a network of solid cords with which the hypoblastic diverticula are connected. In the meantime blood-vessels are developed in the mesoblast lying between the cylinders, which vessels become united as branches with the umbilical vein passing through the liver. Hollow processes also extend themselves from the hypoblastic diverticula and stretch into the solid cylinders of the hepatic parenchyma; but the greater part of this remains solid for a time, consisting of reticulated strings of cells between which there is nothing but blood-vessels.

According to Foster and Balfour, following Remak and the earlier observers, the cellular elements of the gland are stated to derive their origin from the hypoblast, and the mesoblast is mainly converted into blood-vessels and the fibrous tissue of the ducts.

The gall-bladder is formed by extension from the wall of the main duct.

The blood-vessels formed in the liver become branches of the main vein which passes through the cellular mass. These are distinguishable as an anterior and posterior set, the arrangement of which is such that the blood flows from stem to branches in the anterior, and from branches to stem in the posterior. Thus the distinction is established between portal and hepatic veins (see the Development of the Veins).

The solid cylinders of the blastema represent the hepatic lobular tissue, where the ducts are reticulated; the hollow processes the larger hepatic ducts, which do not communicate with one another. The origin of the finest ducts is not known; perhaps each cellular cylinder may be looked upon as a collection of hepatic cells, in the centre of which is the minute duct, according to the view now taken of the structure of the adult liver (Foster and Balfour).

The gall-bladder is at first tubular, and then assumes a pyriform shape. It first appears in the second month. The alveoli in its interior appear about the sixth month. At the seventh month it first contains bile. In the fœtus its direction is more horizontal than in the adult.

The following are the principal peculiarities in the liver of the human fœtus:—

Size.—At the sixth or seventh week, the liver is so large that it is said to constitute one-half of the weight of the whole body. This proportion gradually decreases as development advances, until at the full period the relative weight of the fœtal liver to that of the body is as 1 to 18.

In early fœtal life, the right and left lobes of the liver are of nearly equal size. Later, the right preponderates, but not to such an extent as after birth. Immediately before birth the relative weight of the left lobe to the right is nearly as 1 to 1·6.

Position.—In consequence of the nearly equal size of the two lobes, the posi-

tion of the fœtal liver in the abdomen is more symmetrical than in the adult. In the very young fœtus it extends over nearly the whole of the abdominal cavity: at the full period it still descends an inch and a half below the margin of the thorax, overlaps the spleen on the left side, and reaches nearly down to the crest of the ilium on the right.

Form, Colour, &c.—The fœtal liver is considerably thicker in proportion from above downwards than that of the adult. It is generally of a darker hue. Its consistence and specific gravity are both less than in the adult.

During fœtal life, the umbilical vein runs from the umbilicus along the free margin of the suspensory ligament towards the anterior border and under surface of the liver, beneath which it is lodged in the umbilical fissure, and proceeds as far as the transverse fissure. Here it divides into two branches; one of these, the *ductus venosus*, continues onward in the same direction, and joins the vena cava.

Fig. 792.

Fig. 792. — EARLY CONDITION OF THE LIVER IN THE CHICK ON THE THIRD DAY OF INCUBATION (from J. Müller). ½.

1, the heart as a simple curved tube; 2, 2, the intestinal tube; 3, conical protrusion of the coat of the commencing intestine, on which the blastema of the liver (4) is formed; 5, portion of the layers of the germinal membrane, passing into the yolk-sac.

The other, which is the larger branch (the trunk of the umbilical vein), turns to the right along the transverse or portal fissure, and ends in the vena portæ, which, proceeding from the veins of the digestive organs, is in the fœtus comparatively of small dimensions. The umbilical vein, as it lies in the umbilical fissure, and before it joins the vena portæ, gives off large lateral branches, which pass directly into the right and left lobes of the liver. It also sends a few smaller branches to the square lobe and to the lobe of Spigelius.

After birth the umbilical vein becomes obliterated from the umbilicus up to the point of its giving off branches to the liver. The ductus venosus is also obliterated, but the veins which were given as branches from the umbilical vein to the liver remain in communication with and appear as branches of the left division of the portal vein.

The Pancreas.—This organ takes its origin in a mass of mesoblastic tissue, which thickens the wall of the duodenum close to the place where the rudiment of the liver is first seen, but placed more to the left side. This mass may be seen on the fourth day in the chick. There is, however, also a diverticulum from the primary wall of the intestine or hypoblast. Some doubt prevails, as in regard to the liver, with respect to the exact share of the hypoblastic and mesoblastic elements in the formation of the glandular cells. The main duct and its branches undoubtedly owe their origin to diverticula proceeding from the intestinal hypoblast, and the epithelial lining of the ducts is certainly derived from that source. By those who, adopting the most probable view, consider that the glandular cells also arise from the hypoblast, solid processes of that layer are described as stretching into the mass of mesoblast. Into these the diverticular cavities subsequently extend in more than one

main division. The blood-vessels and the connective tissue of the gland are undoubtedly due to the mesoblastic elements, and these are very soon combined with the parts proceeding from hypoblast.

Fig. 793.

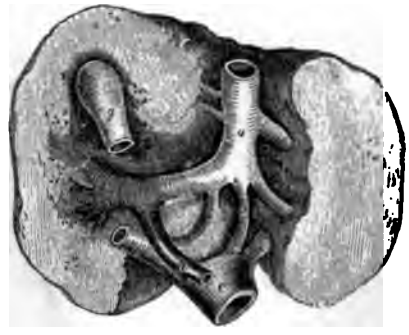


Fig. 793.—UNDER SURFACE OF THE FŒTAL LIVER, WITH ITS GREAT BLOOD-VESSELS, AT THE FULL PERIOD.

a, the umbilical vein, lying in the umbilical fissure, and turning to the right side, at the transverse fissure (*o*), to join the vena portæ (*p*): the branch marked *d*, named the ductus venosus, continues straight on to join the vena cava inferior (*c*): some branches of the umbilical vein pass from *a* into the substance of the liver; *g*, the gall-bladder.

The development of the spleen is described along with that of the lymphatic system at p. 877.

THE LUNGS, TRACHEA, AND LARYNX, &c.

The very first appearance of the pulmonary organs in birds and mammals consists of a single median diverticulum from the ventral wall of the œsophagus immediately behind the fourth visceral cleft. The lower extremity of this protrusion soon becomes dilated towards the two sides, while its root communicating with the gullet remains single. These primitive protrusions or tubercles are visible in the chick on the third day of incubation, and in the embryoes of mammalia and of man at a corresponding stage of advancement. Their internal cavities communicate with the œsophagus, and are lined by a prolongation of the hypoblast.

The diverticulam of hypoblast is surrounded by a mass of mesoblastic

Fig. 794.

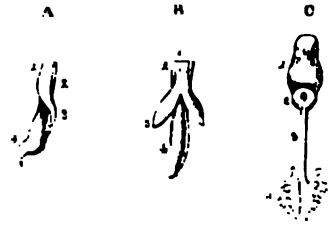


Fig. 794.—SKETCH ILLUSTRATING THE DEVELOPMENT OF THE RESPIRATORY ORGANS (from Rathke).

A, œsophagus of a chick, on the fourth day of incubation, with the rudimentary lung of the left side, seen laterally; 1, the front, and 2, the back of the œsophagus; 3, rudimentary lung protruding from that tube; 4, stomach. B, the same seen in front, so as to show both lungs. C, tongue and respiratory organs of embryo of the horse; 1, tongue; 2, larynx; 3, trachea; 4, lungs seen from behind.

cells, so that the pulmonary parenchyma, like that of the glands, owes its origin to both hypoblastic and mesoblastic elements. The substance of the mesoblast, thickening round the primary diverticula, becomes penetrated by secondary diverticula formed from the hypoblastic processes; these are succeeded by tertiary branches which develop the

bronchia, and ultimately have the air-cells formed as their terminations. The formative process consists essentially in the budding of hypoblastic

Fig. 795.

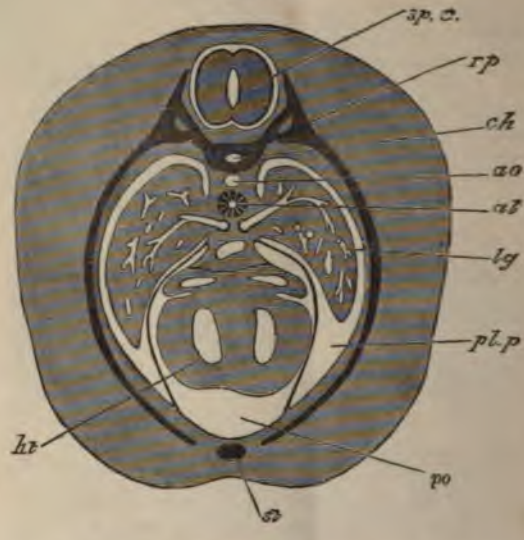


Fig. 795.—Section through an advanced embryo of a bird to show the relations of the pericardial and pleural cavities (from Balfour).

ht, heart; *p*, pericardial cavity; *p.l*, pleural cavity; *lg*, lung; *al*, alimentary tract; *ao*, dorsal aorta; *ch*, notochord; *rp*, rib; *st*, sternum; *sp.c*, spinal cord.

into mesoblastic substance; the hypoblast furnishing the lining epithelium of the tubes, and the mesoblast the other tissues, such as muscular fibres, cartilage, blood-vessels, elastic tissue, &c.

The division into larger lobes externally, three in the right and two in the left lung, may be seen at a very early period in the human fœtus. As the bronchial subdivision extends within the lungs, a tubercular or coarsely granular appearance is seen over the outer surface, as observed by Kölliker in the human fœtus in the latter half of the second month. This is produced by the primitive air-cells placed at the extremities of ramified tubes, which occupy the whole of the interior of the organ: the ramification of the bronchial twigs and multiplication of air-cells go on increasing, and this to such an extent that the air-cells in the fifth month are only half the size of those which are found in the fourth month.

In birds the principal air-sacs, three in number, are formed in direct connection with the lung in the course of its early development, and the rudiments of these sacs may be seen at an early period, as bulging constituent parts of the rudimentary lungs.

Pleuræ.—Each lung receives a covering externally from the lining membrane of the common pleuro-peritoneal cavity of its own side. This is at first only on the outer side; but, as the lungs enlarge, a fissure separates their solid substance from the outer wall of the œsophagus, and the pleura is carried round the lung-mass so as to encircle the gradually narrowing root of each lung. The two pleuræ remain separated by the mediastinum and heart, round which they have extended.

Pulmonary Vessels.—The blood-vessels of the lungs, which arise in the mesoblastic tissue, seem to be of comparatively late formation, penetrating into the pulmonary tissue only on the twelfth day in the chick. In mammals the blood-vessels are formed in the same manner in the pulmonary mesoblast. In birds, as before mentioned, the pulmonary arteries proceed one from each of the fifth arterial aortic arches, but in mam-

mals both right and left pulmonary arteries are connected with the fifth arch of the left side. The manner in which they become connected with the vessels formed in the lung-substance, and in which a union is established between the pulmonary veins and the left auricle, has not yet been ascertained.

Thyroid Body.—This seems to be the proper place at which a reference may be made to the two organs of doubtful nature—viz., the thyroid and thymus bodies—which have generally been ranked with the vascular glands, but which from their development appear to have also some close connection with the anterior part of the alimentary canal.

The thyroid gland takes its origin both in birds and mammals (W. Muller (No. 263), Kölliker (No. 28, i., p. 869), by a diverticulum from the ventral wall of the pharynx opposite to the place where the aortic bulb divides into the anterior visceral arches, and it is conjectured that it may be homologous with the endostyle or ventral diverticulum of the pharynx in the lampreys. It consists at first of a mass of hypoblast which in birds is hollow, but in mammals is solid; and in both classes large glandular cells are soon developed, which Kölliker represents in the rabbit as taking the form of reticulated cellular cords. The hypoblastic part soon acquires mesoblastic elements, in which blood-vessels and fibrous tissue are rapidly developed, and the thyroid body becomes highly vascular.

In birds the primary diverticular mass loses its connection with the pharynx at an early period, divides into two separate parts, and is carried back in the neck along with the elongation of that part, so as to form two very distinct compact spheroidal bodies situated near the division of the trachea.

In mammals the thyroid mass becomes somewhat bilobed, the larger lateral parts remaining united by the isthmus across the trachea.

In man the first origin of the thyroid body has not yet been observed. In the second and third months the glandular cords and follicular cavities begin to appear, and these go on increasing rapidly in the following months.

The Thymus Gland.—According to Kölliker's observations in the rabbit, this body is originally of epithelial nature, and arises as a diverticulum from an anterior pair of the visceral clefts, forming a small longish thick-walled triangular sacculus with two hollow tubular cornua. It soon divides into lobes, and in these gland-cells make their appearance, blood-vessels and other tissues being added from mesoblastic sources.

The view taken by Kölliker as to the origin of the thymus has been confirmed by the observations of Stieda in the pig and sheep, in which he found the thymus to arise as a paired outgrowth from the remnants of two visceral clefts; and he and Wölfler attribute a similar mode of origin to the thyroid body. (273 and 274.)

V. DEVELOPMENT OF THE URINARY AND GENERATIVE ORGANS.

I. GENERAL VIEW.

The development of the permanent urinary and generative organs has long been known to be intimately associated with that of the embryonic glandular organs named the primordial kidneys, or after their discoverer, C. F. Wolff, the Wolffian Bodies. This association was first ascertained

by H. Rathke, Oken, and Joh. Müller more than fifty years ago, and its fuller knowledge of its nature has been illustrated by numerous embryologists in investigations of more recent date (Bornhaupt, Kobelt, Kölliker, Waldeyer, Semper, Balfour and others).

Wolffian Bodies and Segmental Organs.—According to the two last named observers, the Wolffian bodies are the representatives in a certain stage of their development of a set of tubular glands or excretory organs existing in all vertebrates and in a certain number of invertebrate animals, especially annelida, to which the general name of *segmental organs* may be given, from their relations to the metameric somites of the body.

Fig. 796.

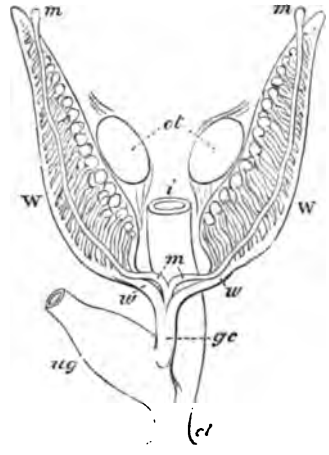


Fig. 796.—Diagrammatic outline of the Wolffian bodies in their relations to the rudiments of the reproductive organs. (A. T.)

ot, seat of origin of the ovaria or testes; W, Wolffian bodies; *w. w*, Wolffian ducts; *m m*, Müllerian ducts; *ge*, genital cord: *ug*, sinus urogenitalis: *i*, intestine; *cl*, cloaca.

It was first shown by Rathke in 1826 that the Wolffian bodies of all vertebrates consist of glandular tubes with which are combined vascular glomeruli of the same general nature as those of the adult kidney; and recent researches have further shown that an essential structural character of the bodies in question, in the great majority of animals in which they are found, is the existence at an early stage of development of an opening on the one hand of a certain number of their tubes into the body cavity of the embryo, and on the other, of one or more of their main ducts into the cloaca or hinder part of the alimentary canal.

In the amniota, that is in reptiles, birds and mammals, while the greater part of the segmental organs known as the Wolffian bodies becomes atrophied and disappears in early fœtal life, a further development of organs of a similar structure gives rise to the permanent kidneys, and parts of the embryonic segmental organs with their ducts contribute to the formation of the adult male and female generative organs.

Distinction of Pronephros, Mesonephros, and Metanephros.—The simultaneous researches of Semper and Balfour in elasmobranch fishes have led them to distinguish three typical or fundamental parts of the segmental organs, all of which agree more or less, 1st, in their characteristic renal or combined tubular and glomerular structure, and 2nd, in their opening on the one hand anteriorly and internally into the abdominal cavity, and on the other posteriorly into the cloaca.

These bodies may be regarded as three serial divisions of an entire

segmental apparatus extending on each side of the body of a vertebrate embryo from the head or region of the heart to the cloaca in the hinder part of the body. The middle division, which in the embryonic condition is the largest, is the Wolffian body before referred to: the anterior, much smaller and less constant among animals, is the head-kidney of Balfour and Sedgwick; and the posterior one, later of being formed than the other two, corresponds to the permanent kidney of the amniota. To these several divisions of the segmental apparatus Ray Lankester has given the appropriate designations of Pronephros, Mesonephros and Metanephros.

Wolffian and Müllerian Ducts.—Each of these three divisions of the segmental organs possesses an excretory duct—viz., the Müllerian duct belonging to the pronephros or head-kidney, the Wolffian duct to the mesonephros or Wolffian body, and the ureter to the metanephros or permanent kidney of the amniota.

Fig. 797.

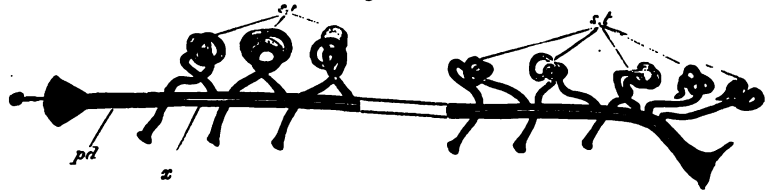


Fig. 797.—Diagram of the primitive condition of the kidney in an elasmobranch embryo (from Balfour).

pd, segmental duct; opening at *o*, into the body cavity and at its other extremity into the cloaca; *x*, line of separation between the Wolffian duct above and the Müllerian duct below; *st*, segmental tubes, opening at one end into the body cavity and at the other into the segmental duct.

The general nature and relations of these segmental organs, considered as embryonic structures, and as the foundation and precursors of the permanent urinary and internal generative organs, will be best explained by following Balfour's very clear statement of the principal steps of their development in elasmobranch fishes.

Origin and Formation of the Segmental Organs.—The segmental organs of the vertebrates originate in a long shaped mass of formative cells, which, at a period corresponding to the latter half of the second day of incubation in the chick, is seen to be separated from the mesoblast in a recess between its mesial or protovertebral and its lateral columns, and which has hence received the name of *intermediate cell-mass*. The separation of this cell-mass as a distinct cord or column begins in the region of the fifth somite or protovertebra in the chick, and extending from thence backwards to near the hinder part of the primitive gut, it finally reaches the cloaca with which it is connected. It is at first solid, but soon acquires a lumen within, and thus forms a tube, the greater part of which corresponds with that which was earlier known as the Wolffian duct, but which in its entirety, according to the more recent views before quoted, may be named the *segmental duct*. This column with its duct at the same time changes its position by sinking down in a ventral direction, so that it comes to project in the body-cavity, and soon, by a rapid increase of formative substance round

it, the whole forms a longitudinal column on each side of the mesentery between the parietal and visceral divisions of the mesoblast.

Segmental Tubes.—Within this columnar mass a series of tubular offsets are early developed (Wolffian tubes) which have the general form of short

Fig. 798.

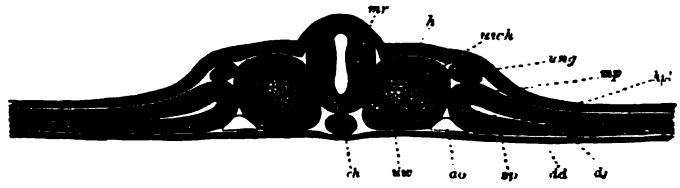


Fig. 798.—TRANSVERSE SECTION THROUGH THE EMBRYO OF THE CHICK AND BLASTODERM ON THE SECOND DAY (from Kölliker).

d d, hypoblast; *ch*, chorda dorsalis; *u w*, primordial vertebræ; *m r*, medullary plates; *h*, corneous layer or epiblast; *u w h*, cavity of the primordial vertebral mass; *m p*, mesoblast dividing at *s p* into *h p l*, body wall, and *d f*, visceral wall; *w g*, Wolffian duct, beginning in the intermediate cell-mass. (See also figs. 690 and 692.)

transverse cæca directed inwards and connected externally with the main segmental duct. These tubes in the lower vertebrates, and in reptiles among the amniota, correspond closely in number with the vertebral or muscular somites in the region which they occupy; but in birds and mammals, though at first nearly so corresponding, they come later to

Fig. 799.

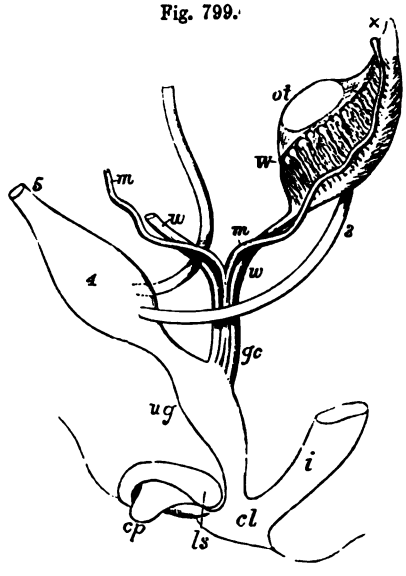


Fig. 799. — DIAGRAM OF THE PRIMITIVE URO-GENITAL ORGANS IN THE EMBRYO PREVIOUS TO SEXUAL DISTINCTION.

The hinder parts are shown chiefly in profile, but the Müllerian and Wolffian ducts are seen from the front, entire upon the left and cut short upon the right side. 3, ureter; 4, urinary bladder; 5, urachus; *ot*, the genital ridge from which ovary or testicle is afterwards formed; W, left Wolffian body; *x*, anterior part from which the vasculosi are afterwards developed; *w. w*, right and left Wolffian ducts; *m. m*, right and left Müllerian ducts uniting together and with the Wolffian ducts in *gc*, the genital cord; *ug*, sinus urogenitalis; *i*, lower part of the intestine; *cl*, cloaca; *cp*, elevation which becomes clitoris or penis; *ls*, fold of integument from which the labia majora or scrotum are formed.

be more numerous by the addition both of original and of secondary tubes. These may be named the *segmental tubes*. In its primary form, therefore, the segmental organ might be described as consisting of a main duct or canal with a number of cæcal tubuli branching from it or leading into it laterally.

Very soon, however, a great modification and complication in the structure and relations of this organ takes place in three ways which may be shortly stated as follows :—1st, by the formation of openings from the inner ends of some of the segmental tubes, and later of the segmental duct itself into the peritoneal or body cavity at its upper or dorsal part; 2nd, by the increased growth and convolution of the tubules, especially of the mesonephros, and by the development of vascular glomeruli in connection with them; and 3rd, by the formation of a new collateral duct in the vicinity of the original segmental duct, and certain changes in the association of the segmental tubes with the two ducts which thus come to take the place of the original segmental duct. These latter changes are of such a nature that the greater number of the

Fig. 800.

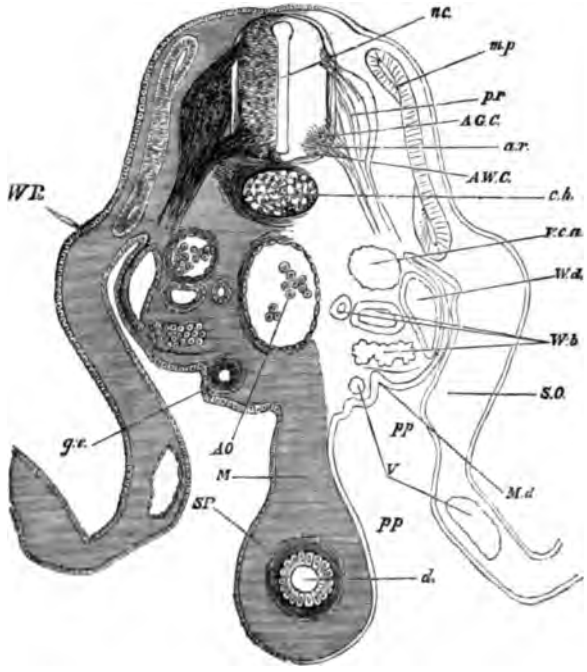


Fig. 800.—SECTION THROUGH THE LUMBAR REGION OF AN EMBRYO CHICK OF FOUR DAYS (from Foster and Balfour).

nc, neural canal; *pr*, posterior root and ganglion of a spinal nerve; *ar*, anterior root; *mp*, muscle-plate; *ch*, notochord; *WR*, Wolffian ridge; *AO*, aorta; *Vc a*, cardinal vein; *Wd*, Wolffian duct; *Wb*, Wolffian body with glomeruli; *ge*, germinal epithelium; *Md*, depression forming the commencement of the Müllerian duct; *d*, alimentary canal; *M*, mesentery; *SO*, body-wall; *SP*, visceral wall; *V*, blood-vessels; *pp*, pleuro-peritoneal space.

glandular tubules forming the mesonephros remain connected with that part of the segmental duct which becomes the Wolffian duct, and are thus brought to a common opening in the cloaca; while (as ascertained in some vertebrates, though not in all) some of the anterior tubules are left in connection with the separate or newly-formed duct,

which, having been originally discovered by Joh. Müller in 1830, h since been named the Müllerian duct.

The ureter may be looked upon as an offset from the hinder part the Wolffian duct, and the metanephros of the elasmobranchs consists a set of segmental tubes developed in connection with this duct, po sessing the same glandular and glomerular structure as the mesonephr and occupying a situation which is on the dorsal aspect of the Wolffi duct and near its hinder part. The characteristic feature in the develo ment of the urino-genital system in the amniota is according to Balfo the formation of a metanephros or permanent kidney, and the comple or partial disappearance of the other two parts of the segmental organs viz., the pronephros and mesonephros.

The Müllerian and Wolffian ducts stand in a different relation to t productive organ in the two sexes. In the female the Müllerian du becomes developed into the whole length of the genital passages, and t Wolffian duct almost entirely disappears. In the male, on the oth hand, the Wolffian duct becomes converted into the excretory duct (v deferens) of the testicle; while the Müllerian duct undergoes atrophy an has no permanent existence.

Fig. 801.

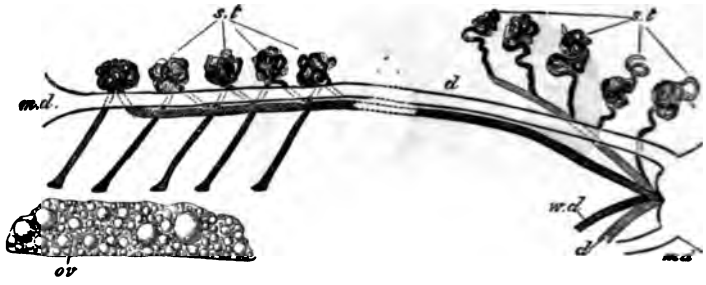


Fig. 801.—DIAGRAM OF THE ARRANGEMENT OF THE URINO-GENITAL ORGANS IN AN ADULT FEMALE ELASMOBRANCH (from Balfour).

m.d., Müllerian duct; *w.d*, Wolffian duct; *s.t*, segmental tubes; five of them a represented with openings into the body cavity, and five posteriorly correspond to t metanephros; *ov*, the ovary; *d*, ureter.

In connection with the conducting passages of both sexes there a found in later life vestiges of those of the embryonic structures whi are not employed in the production of the permanent generative orga and these vestiges are of considerable interest in their bearing upon t history of the changes by which the permanent organs are formed.

Genital Ridge and Germ-Epithelium.—In all the Vertebrates t productive gland of the generative system, ovary or testicle, takes i origin from formative blastema situated on the mesial side of ea Wolffian body or mesonephros at an early period of embryonic life, a there is in the commencement a close connection between the ori of the first elements of the sexual products, ova or spermatic ce and a portion of the epithelium which lines the body cavity in th region. Here an elevation of the blastema and thickened epitheliu marks the presence of the ***genital ridge***, and the name of ***germ-epitheli***

is given to the more developed portion of the epithelium from which the generative elements are derived.

In the lower vertebrates the anterior part of the Müllerian duct is connected with the pronephros, and the opening by which this duct communicates at its anterior extremity is probably one of the peritoneal apertures of that portion of the segmental organs. Among the amniota the pronephros or head-kidney is as yet only known in birds by the researches of Sedgwick and Balfour; but, according to the views of the latter, it seems probable that the anterior part of Müller's duct is, in reptiles and mammals as well as in birds, homologous with the duct of the pronephros. Although, therefore, the tubular part of the pronephros is not developed in these animals, there is reason to hold that the type of development of their urogenital passages is, in the main, the same as in birds and the lower vertebrates.

The relation of the origin of the productive sexual organs to the mesonephros, though not yet fully ascertained, is known to be closer in the male than in the female sex. Thus there is good reason to believe that, while in both sexes, as already stated, the productive elements are derived from the germinal cells of the genital ridge, there are

Fig. 802.

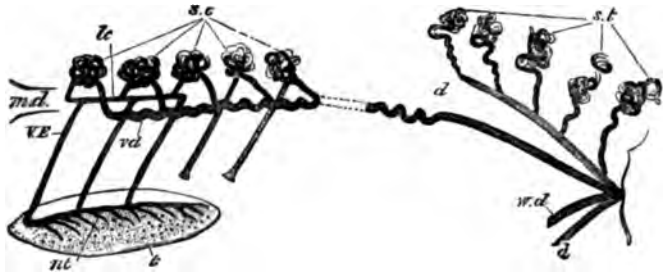


Fig. 802.—Diagram of the arrangement of the urino-genital organs in an adult male elasmobranch (from Balfour).

m.d., rudiment of Müllerian duct; *w.d*, Wolffian duct, serving at *vd* as vas deferens; *s.t*, segmental tubes, two represented with openings into the body cavity; *d*, ureter; *t*, testis; *nt*, canal at the base of the testis; V.E, vasa efferentia; *lc*, longitudinal canal of the Wolffian body.

differences in the further development of the organs containing the generative elements, as in the Graafian follicles in the one and the spermatic tubes in the other.

The External Organs.—With regard to these organs, it is sufficient to remark in this place that the structural elements from which they take their origin are essentially the same in the two sexes, and that their special sexual characters in the male and female depend rather upon differences in the degree and manner of their development than upon any fundamental disparity in their nature. The nature of the process will be more fully explained hereafter.

In all mammals, with the exception of the monotremata, the distinctive development of the external organs is preceded by the separation of the cloaca internally into an anterior urogenital and posterior anal part, which when the proctodæum is perforated open separately on the surface.

The history of the development of the parts composing the external organs in connection with the formation of their special sexual characters will be described in a later part of this chapter.

II. FURTHER DEVELOPMENT OF THE PERMANENT URINO-GENITAL ORGANS.

I. THE KIDNEYS.

The origin of the kidneys as a metanephros in connection with the hinder part of the Wolffian body on its dorsal aspect has already been adverted to. Kölliker, following Kupffer and Lieberkühn, and from his own observations, has described the first appearance of the kidney in mammals as taking place by the development of a tubular diverticulum from the Wolffian duct near its termination in the cloaca. This tube represents the earliest condition of the ureter, and it extends into a mass of mesoblastic cells corresponding or continuous with that of the Wolffian body from which the glandular part of the kidney is gradually developed. The distinction between the tubular or ureter part and that which is to become the parenchyma of the gland becoming more apparent, the latter increases greatly in volume, and rapidly encroaching on the space above the Wolffian body comes to occupy the whole of the region between it and the aorta, and even to project further forward, while other changes in the interior indicate the process of formation of the gland. In the ureter the hinder part elongates as a single tube, but the forepart becomes dilated and subdivided into cæca or wider portions which represent the commencement of the several divisions of the pelvis. These divisions are surrounded by masses of the glandular blastema, into which there pass smaller cæcal tubes which seem to sprout from the pelvic hollows of the original ureter. These tubes then become convoluted, and on their exterior small masses of cells accumulate in which the vascular glomeruli are gradually formed by the development of blood-vessels within them. These blood-vessels remain connected with the external blastema in which they arise by means of a stalk or pedicle, but the glomerulus now comes to be projected into a doubling of the uriniferous tubule in the manner which belongs to all such renal structures. There is at first no distinction between the straight and the convoluted parts of the tubular substance, but this arises later by the gathering together of the convoluted parts in rounded masses towards the exterior, and the elongation of the straighter tubes internally, while at the same time or somewhat later the latter group themselves into bundles which form the pyramids and project into the pelvic calices.

In the human fœtus of eight weeks, the Malpighian glomeruli are already apparent. In the third month the papillæ are formed, and in the fourth the recurved tubes of Henle have become apparent. At first, therefore, the kidneys seem to consist wholly of cortical substance, with only convoluted tubes, and the formation of the straight tubular substance is the result of a later change. The tubes are absolutely, as well as relatively, wider in early fœtal life than in the adult.

In the human fœtus of ten weeks the kidneys have acquired their peculiar bean-like shape with the hilus for the ureter, pelvis and vessels. They are also distinctly lobulated externally, and they retain this form up to the time of birth and during the first year of infancy, and it is not uncommon to find the lobulated form in kidneys of a later period.

Urinary Bladder and Urachus.—The urinary bladder, as already stated in an earlier part of this description, is formed by a dilatation of the stalk of the allantois. In the human fœtus this appears as a spindle-shaped cavity at the end of the second month, the narrower part below being prolonged as the first part of the urethra into the cloaca, while the upper narrowing part extends as the urachus into the umbilical cord, and at an early period in animals is prolonged into the cavity of the allantois.

The ureters terminate in the dorsal wall of that part of the urogenital sinus which is dilated into the urinary bladder.

The urachus is usually a solid cord at a short distance from the bladder, but, according to Luschka, it not unfrequently remains hollow for some length within the umbilical cord.

The spindle shape of the bladder is retained for a long time in the human fœtus.

For the development of the Suprarenal bodies, see p. 841.

Genital Cord.—In both sexes, as was first fully shown by Tiersch (No. 287) and Leuckart (No. 287*) in 1852, the two Wolffian ducts are united by surrounding substance into one cord behind what becomes the base of the urinary bladder; but retaining internally their separate passages until they reach the sinus urogenitalis. With this cord the Müllerian ducts are incorporated posteriorly, so that at one time there are four passages through the whole of the genital cord. The Müllerian ducts next coalesce into one at some little distance from their lower ends, and this fusion progressing upwards and downwards for a considerable space, a single median cavity is produced which lies between the still separate canals of the Wolffian ducts. A large accumulation of tissue in its walls gives to the genital cord great thickness as compared with the neighbouring parts of the ducts where they emerge from its enclosure. The lower part of the united Müllerian ducts thus comes afterwards to form the foundation of the vagina and lower part of the uterus in the female, and the corresponding prostatic vesicle with its occasional vestigial accompaniments in the male, or the uterus masculinus.

Fig. 803.

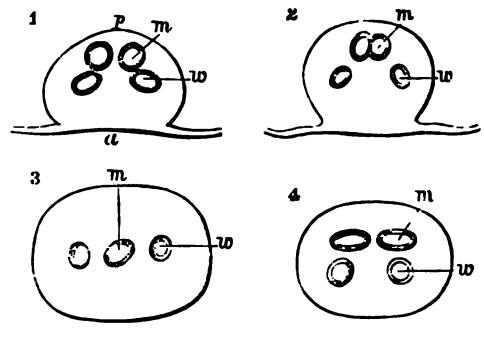


Fig. 803.—Transverse sections of the genital cord in a female calf embryo. Magnified 14 diameters (from Kölliker).

1, near the upper end; 2 and 3, near the middle; 4, at the lower end; *a*, anterior, *p*, posterior aspect; *m*, Müllerian ducts united or separate; *w*, Wolffian ducts.

II. GENERATIVE ORGANS.

In the history of the further development of the generative organs it will be convenient to consider them in the two sexes in succession under the three heads of, 1st, the reproductive glands, or strictly internal

organs; 2nd, the conducting passages or intermediate organs; and 3rd, the external organs.

1. **Reproductive Glands.**—From all recent researches it appears certain, as previously stated, that the reproductive elements of the two sexes take their origin from an identical source, viz., the germ-epithelium of the genital ridge, situated on the mesial side of each Wolffian body. It appears further that in the earliest stages of both the sexes the thickening of the genital ridge by the columnar enlargement of its epithelial cells occurs nearly in like manner; and it is even further stated that in embryoes exhibiting a tendency to be developed as males, an enlargement of some of the germ-epithelial cells into the form of primordial ova is observed of the same kind as in embryoes about to become females. But as development advances, the similarity in the condition of the genital ridge becomes less, and the germ-epithelial cells remain on the whole flatter in the male than in the female.

In the human embryo the distinction of sex begins to be perceptible in the internal organs in the seventh week, and becomes more apparent in the eighth. The reproductive gland is from the first connected with the Wolffian body, with which its blastema seems to be actually in part continuous; and it remains attached to it, or after its disappearance, to the structure which occupies its place, by a fold of the peri-

Fig. 804.

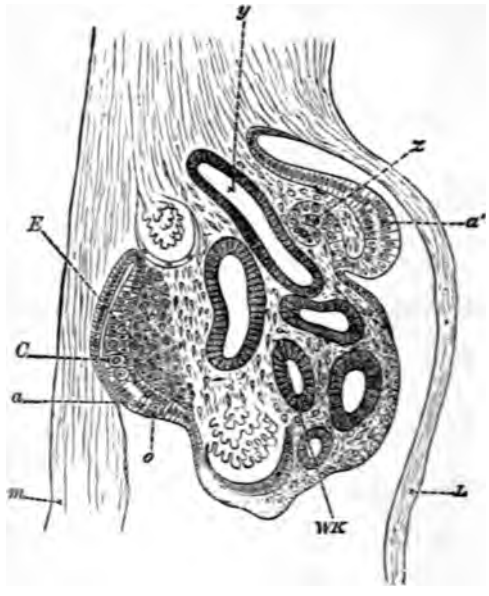


Fig. 804.—Transverse section of the Wolffian body of the chick developing the pronephros and genital gland on the fourth day (from Balfour after Waldeyer).

m, mesentery; *L*, body wall; *a'*, portion of the epithelium from which the involution of the anterior part of the Müllerian duct is taking place; *a*, thickened germinal epithelium in which are seen primitive germ cells, *C* and *o*; *E*, modified mesoblast which will form the stroma of the ovary; *WK*, Wolffian body; *y*, Wolffian duct.

toneal membrane, constituting the mesorchium or mesovarium. Upper and lower bands fix the Wolffian body; the upper passing to the diaphragm may be named the diaphragmatic; the lower, running down towards the groin from the Wolffian duct, contains muscular fibres and constitutes the future gubernaculum testis and round ligament of the uterus.

In birds the distinction of sex is easily recognisable at an early period by the occurrence in the female of an atrophy of the ovary and passages on the right side, while those of the left are fully developed.

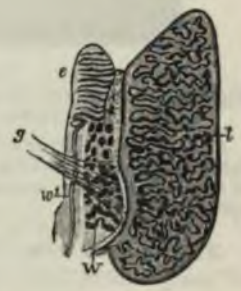
The Testicle.—In male human embryoes at the tenth week already seminal canals are visible, being at first, according to Kölliker, entirely composed of cells, but by the eleventh and twelfth weeks the tubes have become somewhat smaller, longer, and are now branched and possess a membrana propria. There is also by the end of the third month a commencement of lobular division, and the body of the testis is now covered with a condensed layer of fibrous tissue which forms the tunica albuginea. The serous covering is derived from the abdominal peritoneum.

The first origin of the glandular substance of the testis has not been observed in the human embryo, but from the observations of Egli in male embryo rabbits (No. 308) it appears that the epithelial cells, which remain smaller than in the females, soon become connected with the deeper blastema extending towards the Wolffian body, and form strings of cells running into the body of the future testis. These are the commencements of the tubuli seminiferi. Some intimate connection, however, also exists between the tubular structure of the testis and the tubes of the anterior part of the Wolffian body.

Fig. 805.—INTERNAL GENITAL ORGANS OF A MALE HUMAN EMBRYO OF 3½ INCHES LONG (from Waldeyer).

t, body of the testicle with seminal canals formed; *e*, epididymis, or upper part of Wolffian body; *w*, Wolffian body, lower part, becoming paradidymis or organ of Giraldès; *w'*, Wolffian duct, becoming vas deferens; *g*, gubernaculum.

Fig. 805.



The nature of this connection is not fully made out in birds or mammals, but, from the observations of Braun in reptiles (No. 303*), it is probable that the formation of the seminiferous tubes has some close relation with the segmental tubes of the Wolffian body, and in such a way that the germinal epithelium cells are combined with, or enclosed in these tubes, which extend into the body of the testis, and thus come to contain the rudiments of the spermatic cells. (For the development of the spermatozoa from the spermatic cells, see p. 698 of this volume.)

To the probable union between the tubular structure of the testis (rete testis, vasa recta, &c.) with the vas deferens, through the coni vasculosi, by the persistence of some of the tubes in the anterior part of the Wolffian body, reference will be made under the description of the development of the genital passages.

The general result of recent researches appears to be that the elements of the spermatozoa, as formed in the spermatic cells, are derived from the germinal epithelium, while the secreting tubes, which contain the cells, owe their origin to a development of formative mesoblast situated between the germ-epithelium and the Wolffian body, and probably also to the direct extension of some of the segmental tubes from the Wolffian bodies.

The Ovary.—Considered as a glandular organ the ovary differs from the testicle and other glands by the absence of special excretory ducts, and by the separation of its conducting passages from the glandular or productive part of its structure. Like the testicle it begins to manifest its peculiar characteristics by the seventh or eighth week, when the germ-epithelium has attained considerable thickness, and forms a decided

prominence on the mesial side of the Wolffian body. The further development of the glandular part of the organ consists mainly in the formation of ovigerms and ova, and the enclosure of these in Graafian follicles by a peculiar combination or intermixture of the germinal cells from the surface with the deeper blastema which forms the stroma of the organ.

Fig. 806.

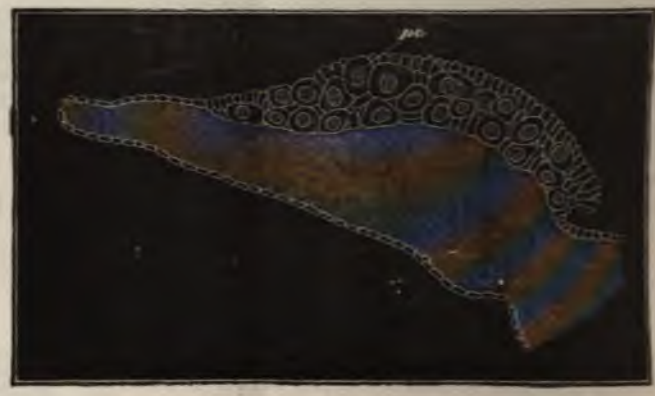


Fig. 806.—Transverse section through the ovary of an embryo shark, showing the germ-epithelium passing into primitive ova (from Balfour).

At *po*, the prismatic germ-epithelium and two primitive ova of which one is still on the surface, the other has sunk below the epithelium; elsewhere the lightly-shaded part of the figure shows the ovarian stroma or lymphatic tissue and the covering of ordinary epithelium.

Primordial Ova.—From the researches of Waldeyer (No. 58) and of many others there cannot now be any doubt that the primitive ova

Fig. 807.

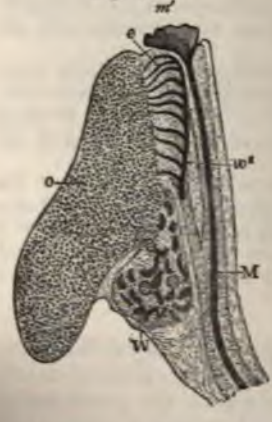


Fig. 807.—Internal organs of a female sheep-foetus of 3½ inches long, or about 14 times Magnified (from Waldeyer).

o, the ovary full of primordial ova; *e*, tube of the upper part of the Wolffian body forming the epoophoron (parovarium of Kobelt); W, the lower part of the Wolffian body forming the paroophoron of His and Waldeyer; *w'*, the Wolffian duct; M, the Müllerian duct; *m'*, its upper fimbriated opening.

are derived from some of the cells of the germ-epithelium which undergo enlargement and subsequently become enclosed in Graafian follicles. But doubts have existed as to the exact manner in which this enclosure takes place, and more especially as to the source of the cellular lining of the follicle which is allied to epithelium and gives rise to the so-called granular membrane of later periods. According to the view first advocated by Waldeyer, the cells

which form this epithelial and granular-cell lining of the follicle proceed originally from the germ-epithelium along with the primitive ova. By Foulis, on the other hand, the origin of these cells has been attributed to an enclosure and differentiation of the cells of the ovarian stroma, while Kölliker's observations have led him to adopt the view that they proceed from the cellular contents of tubes which are connected with the Wolffian body, and remain for a time as vestiges in the base of the ovary (paroophoron ?). But the observations of Ludwig (No. 59) and Balfour (No. 62) seem to show very decidedly that in the lower vertebrates the epithelial lining of the primitive follicle is the direct product of cells which, like the ova themselves, proceed from the germ-epithelium. And though it must be admitted that in the human embryo there are appearances favourable to the view taken by Foulis, the writer of this is induced from his own observations in the human ovary and that of several mammals now to give a preference to the opinion of Waldeyer.

Fig. 808.

Fig. 808.—Section of the ovary of a newly-born child. Highly magnified (Waldeyer).

a, Ovarian or germinal epithelium ; *b*, formation of an ovarian tube ; *c*, *c*, primordial ova lying in the germ-epithelium ; *d*, *d*, longer tube becoming constricted so as to form nests of cells ; *e*, *e*, larger nests ; *f*, distinctly formed follicle with ovum and epithelium ; *g*, *g*, blood-vessels.

In the earliest stages of ovarian development, and for a considerable time afterwards, the germinal cells of the genital ridge undergo a remarkable multiplication, and many of them while still close to the surface, become much larger than the rest, and assume the appearance of primordial ova ; the nucleus expanding into the germinal vesicle, with a distinct nucleolus (or macula) formed within it, and the external protoplasm increasing greatly to form the vitellus or yolk, but, at first, without any enclosing membrane.

As these ovigerms increase in number and size they retire from the surface of the germinal ridge or ovary, and, collecting into groups, they sink into the blastema which lies below the epithelial covering.

At the same time a great increase and extension outwards of the deeper

blastema occurs, and the lymphatic cells (Balfour) of which it consists, present more and more the appearance of connective or fibro-nuclear tissue.

Ovarian Tubes and Nests.—Ere long the groups of ovigerms become enclosed in prolongations of the stroma, which in some animals present a marked tubular form, as described first by Valentin (No. 281), and afterwards more fully by Pflüger (No. 55), and in other instances assume the spherical or grape-like form, so as to deserve rather the name of *nests* which has been applied to them.

Fig. 809.

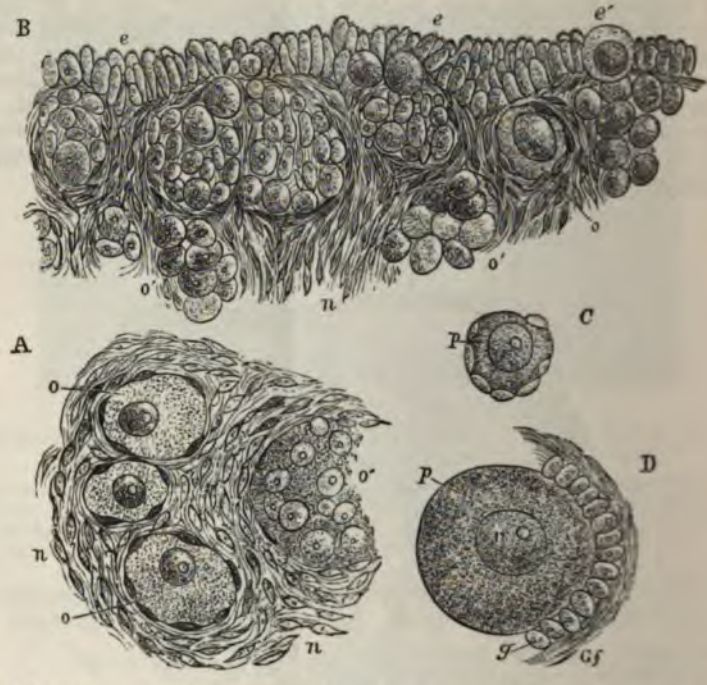


Fig. 809.—Views of the formation of ova and Graafian follicles in the ovary (from Foulis).

A, small portion of the ovary of a human fœtus of 3½ months, showing primordial ova embedded in the stroma; *o*, larger primordial ova; *o'*, cluster of earlier ova; *n*, fusiform corpuscles of the stroma. B, portion of the ovary near the surface in a human fœtus of 7½ months, showing the manner of inclusion of the germ-epithelium corpuscles in groups in the ovarian stroma; *e*, germ epithelium; *e'*, one of the cells enlarging into a primordial ovum before sinking into the stroma; *o*, a larger cell imbedded, becoming an ovum; *o'*, groups of ovigerms or germ cells which have been surrounded by the stroma. C, young ovum from the same ovary, isolated; *p*, yolk protoplasm. D, ovum more advanced, enclosed in condensed stroma, which begins to form a Graafian follicle; *p*, yolk protoplasm; *v*, germinal vesicle with macula; *g*, the enclosed corpuscles now converted into the granular cells; *Gf*, condensed stroma forming the wall of the Graafian follicle.

In these tubes and nests the enlarged cells derived from the epithelium, or ovigerms, are at first of nearly uniform size and appearance, but very soon some of them undergo a greater enlargement, while the others diminish in size, and lose the spherical form. It is not improbable that many of these last may wholly disappear, having served, according to Balfour's view (No. 62), as pabulum, or food, to those which continue to grow. The result of the whole is, however, that one or it may be more, of the cells undergo increased development, and acq

more and more distinctly the characters of ova by the enlargement of the yolk protoplasm and germinal vesicle, while those of the others which survive alter their shape, becoming flattened nucleated cells, and arrange themselves as a more or less complete single layer of epithelium lining the cavity of ovarian stroma in which the primordial ovum is now situated. This cavity is of course the first stage of the Graafian follicle, and the single layer of epithelium lining it, or covering the ovum, is the commencement of the cellular lining which afterwards becomes largely developed in the tunica granulosa.

Enclosure in Graafian Follicles.—While this is going on, and at a time which varies considerably in different animals, but is comparatively early in the human ovary, the ovarian stroma has advanced rapidly so as to enclose first the groups of primordial ova in the tubes and nests, and then the individual ova, with their still very imperfect epithelium; and the wall of the Graafian follicle comes to be formed by a layer of condensed stroma surrounding each space containing an ovum. In many animals the ova remain in this condition for a long time, occupying the germinal stratum at a short distance from the surface of the ovary, as may be most distinctly seen in the ovary of the kitten (see figs. 612 and 613, p. 715), and this stratum of primordial ova is even recognisable in some animals of adult age. In the human ovary the tubes and nests are more equally diffused through the substance of the ovary than in most animals, and, indeed, so much so, and in such numbers, that in the human embryo of from four months up to the period of birth the ovary seems to be an entire mass of primordial ova, with only a slight admixture of the stroma and other tissues; and it is calculated that in the earlier part of this stage the ovaries of the human fœtus may contain not fewer than 70,000 cells having all the characters of primordial ova.

Wall of the Follicle.—When, however, a certain number of the ova begin to be further developed, they retire from the surface into the deeper stroma of the ovary, the most advanced being generally situated at the greatest depth, but at some distance from the hilus. (See fig. 615, p. 719.) When this takes place, we observe, along with the enlargement of the parts both of the ovum and follicle, other changes. The ovarian stroma, or fibro-nuclear tissue, forms layers round the follicle, being firmer and more fibrous externally, and looser with somewhat rounder cells next the cavity, and into the inner of these layers a rich network of blood-vessels soon penetrates. In the more advanced stage, also, we can distinguish a fine homogeneous limiting or basement membrane within.

Granular-cell Lining.—In the interior, and surrounding the ovum, the epithelial cells, which were at first flat and sparse, have now been multiplied, and have assumed the prismatic shape, so as to give a complete and compact lining to the follicle. In subsequent stages the cells of this epithelial lining rapidly increase, so as to form at first several, and then more numerous layers; and when the follicle has attained some size a fissure occurs in these granular cell layers on one side, which leaves the ovum surrounded by a set of the cells which are in contact with the wall of the follicle, while the interval gradually increasing between the ovum so enclosed and the opposite wall of the follicle, there is thus produced the follicular cavity. In the much greater expansion of the follicle which accompanies full maturation of the ovum, it is mainly by the accumulation of fluid in this cavity that the enlargement is produced.

In the ovum itself changes also take place, first of all by some increase of size, which however remains greatly inferior to that of the follicle, so that while the follicle may attain the diameter of from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch, the ovum rarely goes beyond $\frac{1}{200}$ or $\frac{1}{150}$. The reticular structure of the protoplasm in the germinal vesicle becomes more distinct, the macula well defined, the yolk-protoplasm proportionally increased in size and exhibiting yolk corpuscles, and a zona pellucida, or external membrane, gradually makes its appearance externally, being probably due to a condensation of the outer part of the yolk-protoplasm.

The primordial ovum, when first formed, has a diameter of about $\frac{1}{1200}$ to $\frac{1}{1800}''$, and its germinal vesicle, or nucleus, which is then proportionally large, may be about $\frac{1}{2500}$ of an inch in diameter. When the granular epithelium has become cylindrical, and the single ovum enclosed in a simple Graafian follicle begins to sink more deeply into the ovarian substance, its diameter is nearly doubled, while

the Graafian follicle is not larger than sufficient to contain it and its epithelial covering. As the ova approach maturity the Graafian follicle expands rapidly, both by an increase of its fluid and of the granular cells, while the ovum remains of comparatively small size.

2. **The Genital Passages.**—The existence at first of two sets of tubes between the internal productive organs and the external parts has already been adverted to as a feature common to both sexes. The female organs contrast with those of the male in the passages of the first being formed by the large development of one of these sets of tubes, viz., the Müllerian ducts, and in the abortive disappearance of the greater part of the other or Wolffian ducts; while in the male the ducts of Müller suffer in a great measure the abortive retrogression, and the seminal conducting tubes are produced from canals formed out of special parts of the Wolffian body and the whole of the Wolffian duct. But as in all embryoes of whatever sex both sets of tubes are originally present, while a different one of the primary tubes becomes developed into the respective permanent conducting passages, vestiges of the other primary tubes, as already stated, are always present in various degrees in both sexes.

The Female Passages.—In the female, the vagina, uterus, and

Fig. 810.

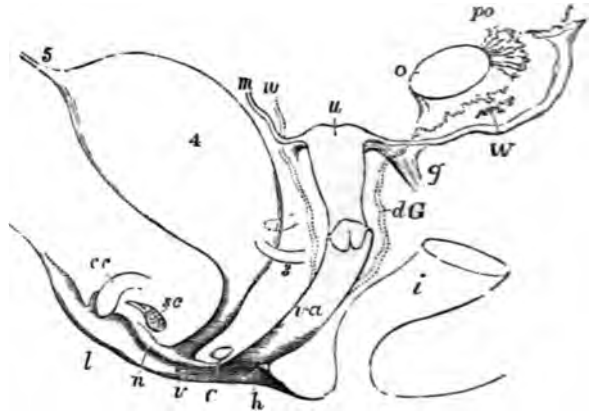


Fig. 810.—DIAGRAM OF THE FEMALE TYPE OF SEXUAL ORGANS.

This and figure 813 represent diagrammatically a state of the parts not actually visible at one time; but they are intended to illustrate the general type in the two sexes, and more particularly the relation of the two conducting tubes to the development of one as the natural passage in either sex, and to the usual occurrence of vestiges of the other tube, as well as to the persistence of the whole or parts of both tubes in occasional instances of hermaphroditic nature.

3, the ureter joining the urinary bladder; 4, urinary bladder; 5, urachus; *o*, the left ovary nearly in the place of its original formation; *po*, parovarium, epoophoron of Waldeyer; W, scattered remains of Wolffian tubes near it, paroophoron of Waldeyer; *d* G, remains of the left Wolffian duct, such as give rise to the duct of Gaertner, represented by dotted lines; that of the right side cut short is marked *w*; *f*, the abdominal opening of the left Fallopian tube; *u*, the upper part of the body of the uterus, still presenting a slight appearance of division into cornua; the Fallopian tube of the right side cut short is marked *m*; *g*, round ligament, corresponding to gubernaculum; *i*, lower part of the intestine; *va*, vagina; *h*, situation of the hymen; C, gland of Bartholin (Cowper's gland), and immediately above it the urethra; *cc*, corpus cavernosum clitoridis; *sc*, vascular bulb or corpus spongiosum; *n*, nympha; *l*, labium; *v*, vulva.

Fallopian tubes, are formed out of the Müllerian ducts. That portion of the ducts in which they become fused together is developed into the vagina, the cervix, and part of the body of the uterus. The next following part of the Müllerian duct, constitutes in animals with horned uteri, the cornu of the uterus; but in the human subject it

Fig. 811.

Fig. 811.—Female genital organs of the human embryo of three months with the remains of the Wolffian bodies (after J. Müller).

a, The body of the uterus notched above; *b*, the round ligament; *c*, the Fallopian tubes; *d*, the ovaries; *e*, remains of the Wolffian bodies.

remains comparatively short, entering into the formation of the upper part of the organ. The remaining upper portion of the Müllerian duct constitutes the Fallopian tube—becoming at first open and subsequently fringed at a short distance from its upper extremity.

Fig. 812.

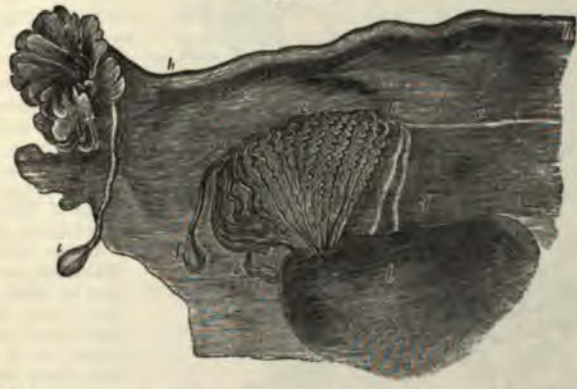


Fig. 812.—Adult ovary, parovarium and fallopian tube (from Farre, after Kobelt).

a, *a*, Epoophoron (parovarium) formed from the upper part of the Wolffian body; *b*, remains of the uppermost tubes sometimes forming hydatids; *c*, middle set of tubes; *d*, some lower atrophied tubes; *e*, atrophied remains of the Wolffian duct; *f*, the terminal bulb or hydatid; *h*, the Fallopian tube, originally the duct of Müller; *i*, hydatid attached to the extremity; *l*, the ovary.

The additional or accessory fimbriæ and openings referred to by Henle in his Handbuch, vol. ii., p. 470, may admit of explanation on the supposition of the duct of Müller having remained open at these places.

In the human embryo of the third month the uterus is two-horned, and it is by a subsequent median fusion and consolidation that the triangular body of the entire organ is produced. The cornua uteri, therefore, of the human uterus cor-

respond with the separate cornua of the divided uterus in animals, and this explains the occasional malformation consisting in the greater or less division of the uterine cavity and vagina into two passages. There is no distinction in the human fœtus in the third and fourth month between the vagina and uterus. In the fifth and sixth months the os uteri begins to be formed, and the neck is subsequently gradually distinguished. Thickening succeeds in the walls of the uterine portion; but this takes place first in the cervix, which up to the time of birth is much larger and thicker than the body of the uterus (Kölliker).

In the meantime the Wolffian bodies undergo a partial atrophy, and their ducts become more or less obliterated and abortive in different parts. The most constant vestige of the Wolffian bodies in the female is the now well-known body of Rosenmüller (No. 277) or Parovarium of Kobelt (No. 285) which has already been described at p. 720 of this volume, the *epoophoron* of Waldeyer, and which, being produced out of the same elements as the epididymis of the male, presents a remarkable resemblance to that body. The canal uniting the radiating tubes (coni vasculosi) of this organ is also usually persistent, but ceases at a short distance below. In the sow and several ruminants, however, and in some Simiæ, the subdivided upper tubular part or epoophoron has disappeared, and the main tube (middle part of the Wolffian duct) remains as the *duct of Gaertner*, a strong, slightly undulated tube, which is traceable, first free in the broad ligament of the uterus, and lower down becoming incorporated with the wall of the uterus and vagina, upon which last it is lost.

The Male Passages.—The conversion of the Wolffian duct into the vas deferens of the testicle was first demonstrated in animals by

Fig. 813.

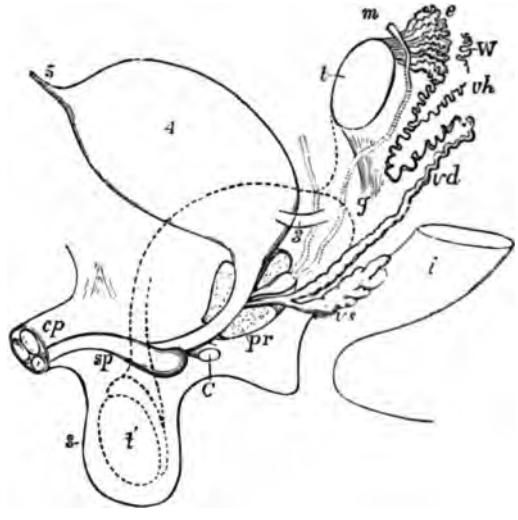


Fig. 813.—DIAGRAM OF THE MALE TYPE OF SEXUAL ORGANS.

Compare with fig. 810 3, ureter; 4, urinary bladder; 5, urachus; *t*, testicle in the place of its original formation; *e*, caput epididymis; *vd*, vas deferens; W, scattered remains of the Wolffian body, constituting the organ of Giraldès, or the paradidymis of Waldeyer; *v h*, vas aberrans; *m*, Müllerian duct, the upper part of which remains as the hydatid of Morgagni, the lower part, represented by a dotted line descending to the prostatic vesicle, constitutes the occasionally existing cornu and tube of the uterus masculinus; *g*, the gubernaculum; *vs*, the vesicula seminalis; *p r*, the prostate gland; C, Cowper's gland of one side; *c p*, corpora cavernosa penis cut short; *s p*, corpus spongiosum urethræ; *s*, scrotum; *t*, together with the dotted lines above, indicates the direction in which the testicle and epididymis change place in their descent from the abdomen into the scrotum.

Rathke (No. 278, Part 4), in correction of the views of J. Müller (No. 279), and was further proved and illustrated by H. Meckel (No. 284) and Bidder (No. 282). Kölliker showed that a similar process occurs in the human embryo, and that a communication established between the seminal tube

of the testicle (rete testis) and some of the upper tubes of the Wolffian body gives rise to the epididymis.

In the male, the Müllerian ducts are destined to undergo little development and are of no physiological importance, while the ducts of the Wolffian bodies, and probably also some part of their glandular substance, form the principal part of the excretory apparatus of the testicle. The united portion of the Müllerian ducts remains as the vesicula prostatica, which accordingly not only corresponds with the uterus, as was shown by Weber (No. 283), but likewise, as pointed out by Leuckart (No. 288), contains as much of the vagina as is represented in the male. In some animals the vesicula prostatica is prolonged into cornua and tubes; but in the human subject the whole of the ununited parts of the Müllerian ducts disappear, excepting, as suggested by Kobelt, their upper extremities, which seem to be the source of the hydatid of Morgagni found between the body of the testicle and upper globe of the epididymis. The excretory duct of the Wolffian body, from the base of that body to its orifice, is converted into vas deferens and ejaculatory duct, the vesicula seminalis being formed as a diverticulum from its lower part (Waldeyer).

With respect to the formation of the epididymis, it appears certain that the larger convoluted seminal tube, which forms the main part and globus minor of that body, arises by a change or adaptation of that part of the Wolffian duct which runs along the outer side of the organ. The vas aberrans or vasa aberrantia of Haller appear to be the remains also, in a more highly convoluted form, of one or more of the tubes of the Wolffian body still adhering to the excretory duct of the organ, and their communication with the main tube of the epididymis receives an explanation from that circumstance. As to the coni vasculosi in the upper part of the epididymis, it has been customary to regard them as produced by a transformation of some of the tubes in the upper part of the Wolffian body, according to the views most fully given by Kobelt; but, from more recent observations, Banks has described the origin of the coni vasculosi as more probably due to a process of development occurring in a new structure or mass of blastema which had been previously observed by Cleland, and which is formed in connection with the upper part of the Wolffian body, and close to the Müllerian duct; while Kölliker holds that sufficient evidence has not yet been adduced in favour of this view.

The coni vasculosi, becoming convoluted, are connected with the body of the testicle by means of a short straight cord, which is afterwards subdivided into the vasa efferentia. The peritoneal elevation descending from the testis towards the lower extremity of the Wolffian body, is the upper part of the plica gubernatrix, and becomes shortened as the testicle descends to meet the lower end of the epididymis; the peritoneal elevation which passes down into the scrotum, and is continuous with the first, is the more important part of the plica gubernatrix, connected with the gubernaculum testis. The spermatic artery is originally a branch of one of those which go to the Wolffian body, and

Fig. 814.

Fig. 814.—View from before of the adult testis and epididymis (from Farre, after Kobelt).

a, *a*, convoluted tubes in the head of the epididymis developed from the upper part of the Wolffian body; *b* and *f*, hydatids in the head of the epididymis; *c*, coni vasculosi; *d*, vasa aberrantia; *h*, remains of the duct of Müller with *i*, the hydatid of Morgagni at its upper end; *l*, body of the testis.

ascend from the surface of the Wolffian body to the upper part of the testis, along the ligaments connecting them; but, as the testis descends, the artery lies entirely above it, the secreting substance of the Wolffian body remaining adherent to it; and hence it is that the organ of Giraldès, which consists of persistent Wolffian tubules, is found in a position superior to the epididymis. (Bain, No. 290).

The Descent of the Testicles.—The testicles, which are originally situated in the abdominal cavity, pass down into the scrotum before birth. The testicle enters the internal inguinal ring in the seventh month of fœtal life: by the end of the eighth month it has usually descended into the scrotum, and, a short time before birth, the narrow neck of the peritoneal pouch, by which it previously communicated with the general peritoneal cavity, generally becomes closed, and the process of peritoneum, now entirely shut off from the abdominal cavity, remains as a separate serous sac. The peritoneal pouch, or processus vaginalis, which passes down into the scrotum, precedes the testis by some time in its descent, and into its posterior part there projects a considerable columnar elevation. There is likewise a fibrous structure attached inferiorly to the lower part of the scrotum, and surrounding the peritoneal pouch above, which may be distinguished as the *gubernacular cord*, both this and the plica gubernatrix being included in the general term *gubernaculum testis* (J. Hunter, No. 276). The gubernacular cord consists of fibres which pass downwards from the sub-peritoneal fascia, others which pass upwards from the superficial fascia and integument, and others again which pass both upwards and downwards from the internal oblique muscle and the aponeurosis of the external oblique; it exhibits, therefore, a fusion of the layers of the abdominal wall. Superiorly, it surrounds the processus vaginalis, without penetrating the plica gubernatrix; and the processus vaginalis as it grows, pushes its way down through the gubernacular cord and dispenses its fibres. By the time that the testis enters the internal abdominal ring, the processus vaginalis has reached a considerable way into the scrotum; and, as the testis follows, the plica gubernatrix becomes shorter, till it at last disappears; but it cannot be said that the shortening of the plica is the cause of the descent of the testicle, and much less that (as has been held by some) the muscular fibres of the gubernacular cord are the agents which effect this change of position. The arched fibres of the cremaster muscle make their appearance on the surface of the processus vaginalis as it descends, while its other fibres are those which descend in the gubernacular cord. (See Cleland, No. 289).

3. **The External Organs.**—In the human embryo, as before stated with respect to animals, the external organs are up to a certain time entirely of the same form in both sexes; and the several organs which afterwards distinguish the male and female externally take their origin respectively from common masses of blastema of precisely similar structure and connections. The common cloaca exists till after the fifth week, and the genital eminence from which the clitoris or penis is formed makes its appearance in the course of the fifth and sixth weeks in front of and within the common orifice. In the course of the seventh and eighth weeks the common orifice is seen to become divided into two parts, viz., the longer slit of the genito-urinary aperture anteriorly, and the narrower and more rounded anal aperture posteriorly: but the exact manner in which the separation of these two apertures takes place has not yet been accurately traced. This process is intimately connected with the formation of the urogenital cord as an independent structure, and is probably mainly effected by the advance from the sides and posteriorly of septal bands which divide the cloaca into a dorsal or anal and a ventral or urogenital part. Somewhat later, or in the ninth and tenth weeks, a transverse integumental band completes the division between the anal and the urogenital orifices, which band forms the whole of the

so-called perineum of the female, and the part of the perineal integument in the male which is situated behind the scrotum; the raphé being most obvious in the male sex.

Two apertures are now seen to occupy the perineal region. Of these the dorsal one or anus is of a rounded form and small size, and is surrounded by a small circular integumental ridge; the anterior or urogenital aperture forms a narrow vertical slit wider behind than before, and running forward into the rudiment of the penis, or clitoris.

The well marked eminence in the integument which forms this rudiment, at first indifferent in the two sexes, is surrounded by a deep circular fold of the integument which encompasses its base, and which in the separate condition is the foundation of the mons veneris and labia majora in the female, and when

Fig. 815.

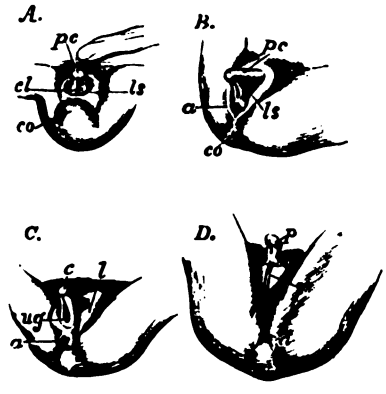


Fig. 815.—DEVELOPMENT OF THE EXTERNAL SEXUAL ORGANS IN THE MALE AND FEMALE FROM THE INDIFFERENT TYPE (from Ecker).

A, the external sexual organs in an embryo of about nine weeks, in which external sexual distinction is not yet established, and the cloaca still exists; B, the same in an embryo somewhat more advanced, and in which, without marked sexual distinction, the anus is now separated from the uro-genital aperture; C, the same in an embryo of about ten weeks, showing the female type; D, the same in a male embryo somewhat more advanced. Throughout the figures the following indications are employed; *pc*, common blastema of penis or clitoris; to the right of these letters in A, the umbilical cord; *p*, penis; *c*, clitoris; *cl*, cloaca; *ug*, urogenital opening; *a*, anus; *ls*, cutaneous elevation which becomes labium or scrotum; *l*, labium; *s*, scretum; *co*, caudal or coccygeal elevation.

united by median fusion, of the scrotum in the male. The lips of the urogenital furrow, which in the female are converted into the nymphæ, and in the male unite as integument below the penis, are both at first precisely the same in all embryoes. In the open condition, which continues until the eleventh or twelfth week, the parts appear alike in both sexes, and resemble very much the more advanced female organs. The rudiments of *Bartholin's* or *Cowper's glands* are, it is said, seen at an early period, near the root of the rudimentary clitoris or penis, on each side of the genito-urinary passage.

In the female, the two external folds of integument enlarge, so as to cover the clitoris as the *labia majora*. The clitoris itself remains relatively smaller, and the groove on its under surface becomes less and less marked, owing to the opening out, and subsequent extension backwards, of its margins to form the *nymphæ*. The vascular bulbs, sunk more deeply in the tissues, remain distinct and separate, except at one point where they run together in the glans clitoridis. The *hymen* begins to appear about the fifth month as a fold of the lining membrane at the opening of the genital passage into the urogenital sinus. Within the vestibule, which is the shortened but widened remains of the urogenital sinus, the urethral orifice is seen, the urethra itself undergoing considerable elongation.

In the male, on the contrary, the *penis* continues to enlarge, and the margins of the groove along its under surface gradually unite from the primitive urethral orifice behind, as far forwards as the glans, so as to complete the long canal of the male urethra, which is therefore a prolongation of the urogenital sinus. This

is accomplished about the fifteenth week. When this union remains incomplete, the abnormal condition named *hypospadias* is produced. In the meantime the *prepuce* is formed, and, moreover, the lateral cutaneous folds also unite from behind forwards, along the middle line or *raphé*, and thus complete the scrotum into which the testicles descend in the course of the eighth month of fœtal life, as before described.

The corpora cavernosa, which are at first separate, become united in their distal portions in both sexes; but the corpus spongiosum urethræ which is also originally divided in all embryoes, and in the female remains so in the greater part of its extent, becomes enlarged in the male in the glans penis, and its two parts united mesially both above and below the urethra, so as to enclose the whole of that tube from the bulb forwards to the glans.

TYPE OF DEVELOPMENT AND ABNORMAL FORMS.

The type of development in the several parts of the genital organs may be stated to differ in the two sexes as follows, viz. :—

1st. In the external organs it is single and homological. 2nd. In the middle organs or passages it is double and heterological. 3rd. In the productive organs it is single and homological as regards the productive elements, but with some difference of the sources from which the containing capsules of the ovary or tubes of the testicle are respectively derived. This is illustrated by the table placed on p. 911.

Accordingly the congenital malformations of the reproductive organs admit of being distributed under the following divisions :—

1st. Abnormal forms attributable to variations in the development of one or more of the external organs in either sex, producing an approach to the form of the other sex.

2nd. Forms referrible to variations in the development of the Wolffian or Müllerian ducts, so as to lead to the greater or less predominance of sexual characters in a part or the whole of either of these passages inconsistent with those prevailing in other parts of the system, or to the coexistence of both sets of passages in whole or in part.

3rd. Extremely rare forms referrible to the possible coexistence of the productive parts of testicles and ovaries in the same individual, which may be combined with more or less of the foregoing kinds of malformation.

As an example of this last form reference may be made to the case described by Heppner, of St. Petersburg, in which microscopic examination showed the presence of small ova in Graafian follicles in the one pair of bodies and of seminiferous tubes and spermatic cells in the other. (No. 334.)

Upon the subject of Hermaphroditism consult Simpson (No. 333).

MALFORMATIONS IN GENERAL.

In the preceding pages we have frequently had occasion to refer to the relation subsisting between the natural development of organs and their abnormal conditions or malformations. There can be no doubt that a considerable number of congenital malformations, more especially those of the nature of *defect*, whether by non-formation or deficient growth of the parts in which they occur, or by want of union between those which naturally fuse together, as well as many abnormal conditions depending on misplacement and altered form and structure, may be attributed in some measure to an arrest of the process of development, or a variation in some part of it, in the earlier stages of embryonic life, and may therefore receive much illustration from the study of the natural process of formation. But comparatively little light has yet been thrown by this study upon the origin of that large class of malformations in which there is *redundance* of parts, either by more or less complete duplicity of the whole body or by an increase in the number of individual parts. At the same time it is obvious that, since in these as in all other malformations the histological and morphological processes of development do not differ essentially in their nature from the natural ones, but are only modifications and variations of them, the

knowledge of the true nature of the abnormal structures must follow closely upon our acquaintance with the natural processes of development.

Upon this extensive subject, which does not come within the scope of this work, the reader is referred to the masterly Essay of Bischoff (No. 312), and other treatises quoted in the Bibliography at p. 918.

Tabular scheme of the CORRESPONDING PARTS of the genito-urinary organs in the two sexes, and of their relation to their EMBRYONAL ELEMENTS :—

ADULT FEMALE.	EMBRYONAL.	ADULT MALE.
I.—GERMINAL RIDGE.		
Ova.	1. Germ-epithelium	**Spermatic cells.**
Stroma of the ovary and Graafian follicles.	2. Deeper blastema with Wolffian stroma.	**Seminal tubes.**
II.—MULLERIAN DUCTS.		
	(Ducts of Pronephros.)	
Fimbriated Fallopian opening and occasional hydatids.	1. Anterior extremity	**Hydatid of Morgagni.**
Fallopian tubes	2. Middle part	Tubes extending from the uterus masculinus.
Vagina and uterus	3. Posterior single part	**Uterus masculinus or prostatic vesicle.**
III.—WOLFFIAN BODIES (MESONEPHROS).		
Smaller tubes of epoopheron, Organ of Rosenmüller (Paro-varium.)	1. Anterior segmental tubes.	**Vasa efferentia and coni vasculosi of the epididymis.**
Paroopheron (Wald.)	2. Posterior segmental tubes	**Paradidymis (Wald.), organ of Giraldès, and vasa aberrantia.**
Round ligament of the uterus	3. Ligament of the Wolffian body.	**Gubernaculum testis.**
IV.—WOLFFIAN DUCTS.		
Main Tube of the Epoophoron	1. Anterior and middle parts	Convoluted tube of the **epididymis.**
Ducts of Gaertner, of some animals.	2. Posterior part	**Vas deferens and vesicula seminales.**
V.—METANEPHROS.		
Kidney	1. Tubular portion	**Kidney.**
Ureter	2. Duct	**Ureter.**
VI.—GENITAL CORD AND SINUS UROGENITALIS.		
Tissue uniting female urethra and vagina.	1. Substance surrounding genital cord.	**Prostate gland.**
Female urethra	2. Urinary pedicle.	**Prostatic portion of urethra** above **vasa deferentia.**
Ostium vaginæ. Hymen	3. Confluence of genital with urinary parts.	**Verumontanum.**
Vestibule	4. Lower part	Lower **prostatic and membranous part of urethra.**
Bartholin's Glands	5. Common blastema	**Cowper's Glands.**
VII.—EXTERNAL ORGANS.		
	1.—*Vascular parts.*	
Crura and corpus clitoridis	*a.* Corpora cavernosa	**Crura and corpus penis.**
Glans clitoridis and vascular bulbe	*b.* Corpora spongiosa	**Glans penis and spongy body.**
	2.—*Integumental parts.*	
Preputium clitoridis	*a.* On genital eminence	**Preputium penis.**
Folds of **nymphæ**	*b.* Lips of genital ridges	**Raphé** below penis.
Mons veneris and **labia majora**	*c.* Cutaneous wall	**Pubis eminence and scrotum.**
Perineum of *female, with raphé...*	*d.* Transverse ano-genital band	**Perineum** of male behind scrotum, with raphé.

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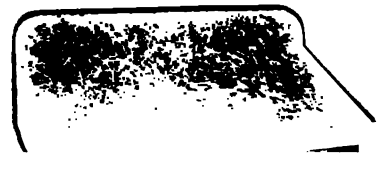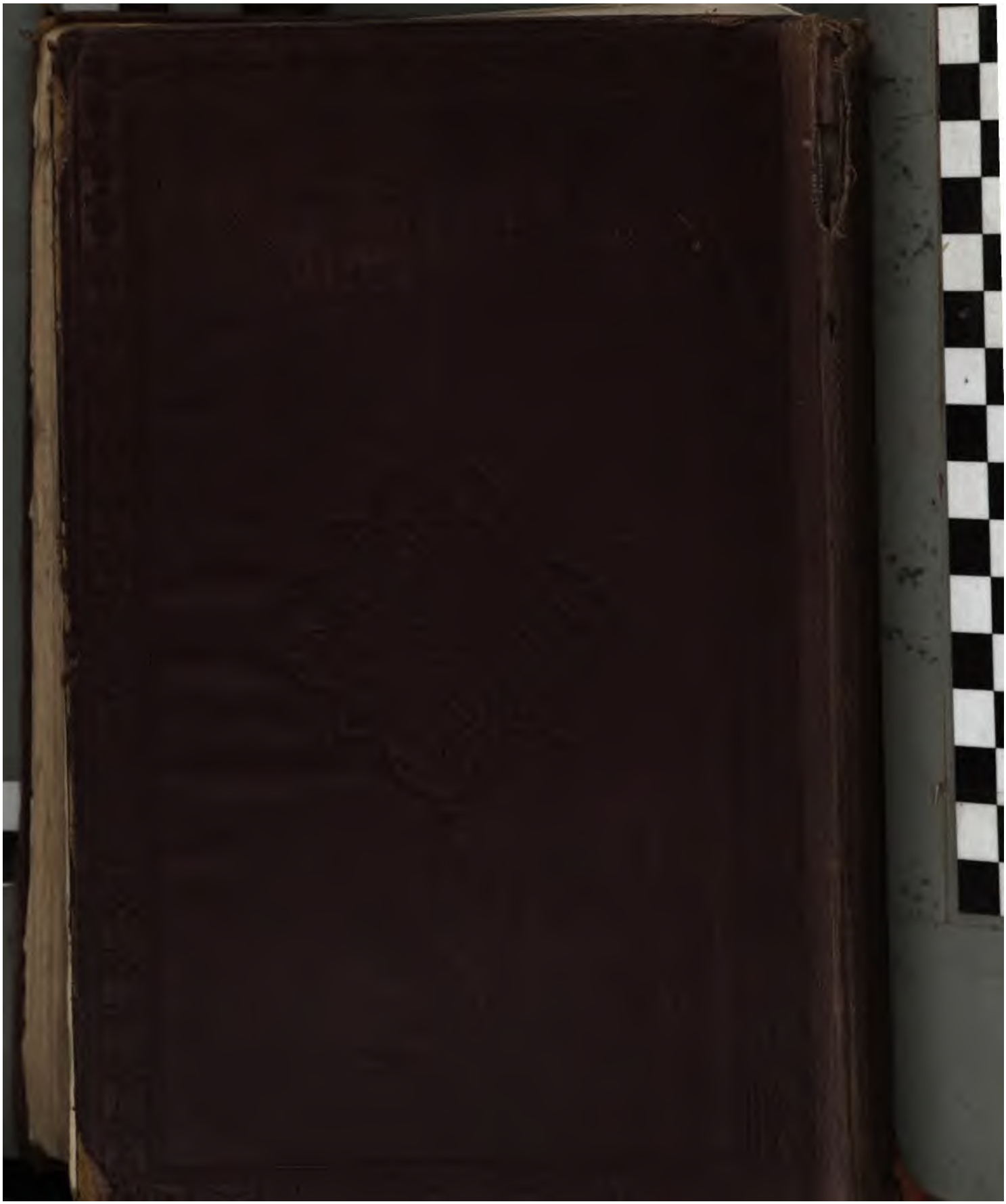
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